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# THE SEPTEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1932

# THE EXTREMES OF NATURE

By Dr. B. S. HOPKINS

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THE human mind is naturally interested in those affairs which may be described by the use of the superlative degree. Long journeys are undertaken to see the highest mountain, to visit the largest building, to view the most beautiful sunsets and to meet the most outstanding individuals of our generation. Keen curiosity is aroused by the largest elephant in captivity or the smallest dwarf of the human race; or by the strongest man, and the tiniest living creature which may be seen under a microscope. We wonder at the most powerful beacon light for the guidance of our night-flying airplanes and the smallest electric lamp that has ever been made. We listen with awe to the tolling of the world's largest bell and look with a feeling almost akin to reverence upon the smallest watch that keeps accurate time. Things of ordinary dimensions are commonplace, but any item whose description requires the use of the superlative challenges our attention and arouses our curiosity.

Nature has given us materials with a wide range of properties and of usefulness. These natural substances are capable of modification by various methods with the development of new properties or the strengthening of those properties which are to be regarded as characteristic. If the watchmaker desires a spring with the greatest possible elasticity and permanence he is interested in knowing what metals may be used and what treatments of these metals are necessary in developing to the highest degree the desired properties. If a machinist requires a hard and tough metal for a bearing he is likewise interested in finding these qualities among the metals and intensifying them until he is satisfied that he is using the best material which is available. The physician who is called upon to fight a disease finds that a number of remedies may be used, but he is anxious to employ the best one for his patient. So our natural curiosity which is stimulated by the use of the superlative degree is reinforced by the needs of our modern civilization. A study of the extremes of nature soon passes far beyond the realm of mere curiosity and establishes itself as a means by which we can measure our progress in solving the problem of selecting the best material to serve our purpose in a certain specific application.

Let us begin our detailed study by attempting to answer the question: What is the heaviest substance known? An answer to this question must be prepared with some care because there are many substances which are extremely heavy, and differences are generally small. Obviously the heaviest substance known to man must be a solid, because solids in general contain matter in the most condensed form. There are many

rocks and minerals which are characterized by their unusual weight and many devices are used to concentrate valuable ores by taking advantage of their great weight. But there are few natural mineral substances which are more than 7 times as heavy as an equal volume of water and there is not one listed that is 10 times as heavy as water. On the other hand, at least 17 of the metals which we use are more than 10 times as heavy as water. The familiar phrase "as heavy as lead" is used to convey the impression of great weight, because every one is familiar with the excessive weight of this common metal. Yet lead is far from being the heaviest of the metals, since gold, mercury, platinum, tantalum, thallium, thorium, tungsten and uranium are all metals which are heavier than an equal volume of lead. In selecting the heaviest metal known, care must be exercised in preparing the sample for examination, because the weight of each metal varies somewhat with its method of preparation. Thus when gold is distilled in a vacuum it has a density of 18.88; when it is drawn annealed its density is 19.26; cast gold has a density 19.3 and when the gold is wrought it has a density of 19.33. So comparisons should be made between metals which have been prepared in a similar manner. The heaviest metal in general use is platinum, whose density varies from 20.9 to 21.7. Closely related to this costly metal are two others, osmium and iridium, which are less familiar than platinum. Both are slightly heavier than platinum. Osmium has a density which varies from 21.3 to 24 and in its most compact form osmium must be given credit for being the heaviest substance known upon our earth.

**What is the lightest substance known?**

As we looked among solids for the heaviest material, so our search for the lightest substance will be among gases, since in these we have matter in its most dilute form. Our familiar comment "as light as a feather" is not very expressive when we are speaking of gases, because a feather is heavier than air, while many of our gases are lighter than air. In speaking of the densities of various gases it is customary to compare their weight with that of an equal volume of air. All gases which are lighter than air are said to have densities which are less than 1. Acetylene, ammonia, carbon monoxide, ethylene, methane, neon and nitrogen are all lighter than air; of this list the lightest gas is methane, and it is about half as heavy as air. The inert gas helium has a density of 0.138, so its weight is about one fourth that of an equal volume of methane and less than one seventh that of air. Although helium is exceedingly light, it is not the lightest gas known, since a liter of hydrogen weighs about half as much as a liter of helium. The lightest gas that we know is hydrogen, whose weight is less than one fourteenth that of air. At the present time hydrogen gas must be considered the lightest substance which is available for general purposes. There is a question however as to whether or not it can fairly be described as the lightest substance known. The worker in high vacua and x-ray tubes deals with streams of electrons and these must certainly be lighter than hydrogen since they may be thought of as being the lightest fragments of disrupted hydrogen atoms.

The most interesting application which depends upon the lightness of hydrogen is in the filling of balloons. Its ability to lift objects from the surface of the earth is truly remarkable, since it can support an object more than 14 times its own weight. When we remember that a man finds difficulty in lifting more than his own weight, we see how great the lifting power of hydrogen is. As a gas for filling balloons it

would be almost ideal except for two facts: it burns very readily and diffuses rapidly through the fabric of the gas bag. The ease and rapidity with which hydrogen burns makes its use in dirigibles extremely dangerous. As a consequence there is a distinct advantage in the use of helium, in spite of its scarcity, its greater initial cost and its lower lifting power.

What substance can be considered the hardest material known?

In order to compare the hardness of various substances it is necessary to agree upon what we mean by the term "hardness" and then to find some method of measuring this characteristic. When an engineer says that a certain metal is hard he may have in mind a variety of things. When the term is applied to the bearings of machinery, it means the ability to resist wear between moving surfaces in the presence of a lubricant; when referred to steel rails and car wheels, it implies resistance to friction without lubrication; in machinery for crushing rocks it refers to the ability to resist both abrasion and shock; in metal which is to be machined, it applies to the difficulty in cutting or working; and in cutting tools it frequently indicates the ability to hold a cutting edge. It is obvious that resistance to wear is quite a different thing from the resistance to cutting. Consequently, a measure of hardness which will permit the comparison of one metal with another is difficult or impossible. The most common means of measuring hardness from the engineering point of view is by determining the resistance to indentation by some especially hardened implement. The Brinell method uses a steel ball 10 mm in diameter which is applied under pressure, the amount of indentation giving an index to the hardness of the metal under examination. Sometimes a cone of hardened steel replaces the ball; sometimes the hardness is estimated by allowing a pointed hammer to fall from a definite height and measuring the height of the rebound; sometimes hardness is determined by the depth of hole cut by a given number of revolutions of a standard drill applied at definite speed and pressure. These various methods of measuring hardness do not give concordant results when they are applied to the same piece of metal. As a consequence we must conclude that our methods of making these measurements are at fault because they do not all depend on the same property of the material being tested. If some one test is selected and this is applied to a number of metals, comparative results are obtained. It is evident, however, that these methods are difficult to apply to the problem of selecting the hardest substance known, because they nearly all contemplate the use of some tool which is harder than the material being tested. It must also be recognized that extreme hardness is frequently accompanied by brittleness. As a result these engineering tests for hardness when applied to all substances might easily result in breaking the object which is under examination.

The mineralogist is intensively interested in the relative hardness of the rocks and minerals which he examines because such a study gives one of the most useful methods for the identification of various native materials. In such a study precise measurement of hardness is not necessary, so there has been devised Mohs' "harness scale," which is based upon the ease with which the smooth surface of a mineral is scratched by another mineral or by a file or knife. Ten well-known minerals are selected and numbered in the order of increasing hardness. These typical minerals composing the scale of hardness are as follows:

1. Talc, including minerals which feel greasy to the hand.

2. Gypsum; those minerals which are easily scratched by the finger-nail.
3. Calcite; difficultly marked by the finger nail, but readily cut by a knife.
4. Fluorite; easily scratched by a knife.
5. Apatite; difficultly scratched by a knife.
6. Orthoclase; scratched by a file; hard enough to scratch glass.
7. Quartz; little touched by a file; scratches glass readily.
8. Topaz
9. Sapphire
10. Diamond.

The intervals between the various members of this hardness scale are not uniform. For example, there is not much difference between the hardness of gypsum, which is No. 2, and that of calcite, which is No. 3, while there is a large difference between the hardness of sapphire, No. 9, and the diamond, No. 10. This last interval is so great that an expert in the study of hard materials assures us that there is greater difference between the hardness of No. 9 and No. 10 than there is between No. 1 and No. 8. Such statements as these justify the opinion that the diamond is the hardest native substance that we know.

There still remains the possibility that some substances which are artificially prepared are harder than the diamond. The high temperatures which have been reached in the electric furnace have made possible the production of many extremely hard products. These are mainly centered around the elements carbon, boron and silicon and the compounds of these elements with certain of the metals. The most important commercial product of this sort is the familiar substance known as carborundum. It is silicon carbide (SiC), which is made by heating a mixture of silica and carbon to a high temperature in an electric furnace. Carborundum has a hardness nearly equal to that of the diamond, and the obvious advantages which it possesses as an abrasive have led to its extensive use in the manufacture of various kinds of grinding tools. Many extremely hard substances have been formed by making the carbides, borides or silicides of such metals as aluminum, calcium, vanadium, titanium, zirconium, molybdenum, tungsten, tantalum and chromium. Silicon boride and aluminum borocarbide are among the hardest artificial products, and a carbide of boron is so hard that it is recommended for use in polishing diamonds. Occasionally the claim is made that one of these products of the laboratory is actually harder than the diamond, but it is unlikely that such a goal has yet been reached. The best conclusion that we can reach is, therefore, that it is undoubtedly still true that the diamond is the hardest substance known.

The most familiar use of the diamond is as our most highly prized gem. The United States buys and wears more diamonds than any other nation. It has been estimated that the diamonds owned in this country exceed 4 billion dollars in value, an average of between $150 and $200 for each family. In spite of these enormous values, it is true that more than half of the world's diamond production is consumed for industrial uses and not as ornaments. For industrial purposes low-grade crystals are used, in such instruments as glass cutters, engravers' tools and lathe tools. A form of diamond known as carbonado or carbon, which does not show a marked crystalline structure, is very tough and durable and may be slightly harder than the gem stones. It is used extensively in making bearings for accurate chronometers, meters and various other laboratory instruments, for making dies for drawing metals out into fine wire; for core drills which are so useful in mining operations; and for saws for cutting stones. Diamond dust finds important use in cutting and polishing gems and other hard materials. South Africa is by far the most important diamond-producing area, nearly 95 per cent. of the world's diamonds being mined there. The United States produces very few

diamonds, Arkansas being the only locality in which diamonds are actually mined. The largest diamond found in this country was located in 1924 and weighed a little over 40 carats. This is quite small when compared with the world's largest, the Cullinan, originally weighing 3,106 carats, which is owned by the King of England; or the Kohinoor, perhaps the most famous of all diamonds, which now weighs a little over 100 carats, although its original weight was about twice as much.

Let us now consider the question: What is the most ductile substance known?

The property of ductility is generally understood to refer to the capacity for being drawn into a wire. A little broader understanding of this term would include also pliability or malleability. So the most ductile substance would be that substance which can be drawn out into the finest wire or hammered out into the thinnest sheet.

These are properties which belong almost exclusively to the metals. In studying the metals with respect to ductility and malleability we must remember that both the purity of the metal and the method of preparation have a profound influence upon ductility and malleability. In general, the presence of impurities tends to make a metal brittle, thereby decreasing the ductility and malleability. A good example of this effect is found in the history of the tungsten filaments now used so universally in our electric light lamps. When attempts were first made to produce a drawn tungsten wire the metal was found to be much too brittle. But when the metal was prepared in a high state of purity and given a skilful heat treatment it was found to be readily ductile. We have reason for believing that many of the less common metals which are now thought to be hard and brittle may prove to be pliable and capable of being worked successfully when we get them sufficiently pure and learn what conditions of temperature are best suited for working them. Sometimes it happens certain impurities present in a metal in definite proportions have the effect of increasing the pliability of a metal. Thus wrought iron, a product which is outstanding for its softness, toughness, malleability and ductility, contains a certain per cent. of carbon, phosphorus and slag, although these impurities in iron ordinarily produce hardness and brittleness. As a result of the varied influences of impurities, we shall do well to pursue our study of ductility without respect to the purity of the metals under consideration.

Gold, silver and copper have long been regarded as the most ductile and most malleable of the metals, although tin, platinum, lead and hot zinc, as well as many of the less common metals, possess these properties in decreasing degree. Gold occupies a position at the head of this list because it has been drawn into wire so fine that it can not be seen without the aid of a microscope. It is reported that gold wire has been made so fine that over 3,000 meters of it are required to give a weight of 1 gram. The significance of these figures is perhaps better understood if we say that an ounce of such a wire would be over 50 miles long. Gold leaf has been made so thin that 1,500 sheets must be stacked together to equal the thickness of an ordinary sheet of printing paper, and a pile one inch high would contain over 300,000 sheets of gold. An ounce of gold beaten out to such extremely thin sheets would cover 189 square feet of surface, while an entire tennis court would be covered by less than one pound of this precious metal. Commercial gold leaf contains a little over 2 per cent. of copper and 2 per cent. of silver, these metals being added for the combined purpose of improving the color and making the thin sheets more rugged in handling. A

thickness of 1/200,000 of an inch is usual in the gold leaf which finds actual use for such purposes as making window signs, artistic designs in glass and monograms on hat bands. Great skill is required for the preparation and handling of such thin sheets of metal. The gold-beaters' art, as carried out today, is essentially the same as that employed by the Egyptians at least 3,000 years ago. This is probably the oldest skilled trade which has successfully resisted the encroachments of the machine age. As carried out in a modern plant, the first step consists in passing an ingot of metal through rollers until it has approximately the thickness of heavy writing paper. This sheet is then cut into one inch squares and 200 of these are placed between the leaves of heavy rice paper about 4 inches square. This book is then slipped into a heavy parchment cover, placed upon a firm pillar and beaten with an 18-pound hammer for 20 minutes. At the end of this process each sheet of gold is nearly 4 inches square, and thinner in proportion than the starting sheet. Each of these is then cut into 4 parts, making 800 sheets in all, which are placed between leaves of gold-beaters' skin, a material prepared from ox gut. Once more the book of leaves is beaten, this time for about an hour and a half. The 800 gold leaves are each cut into quarters and each piece is again placed between sheets of gold-beaters' skin. The final stage in the preparation consists of beating for 4 hours with a hammer weighing about 8 pounds. This produces 3,200 sheets of gold ready to be trimmed and packed between the pages of a paper book. While this description sounds simple the process requires a high degree of intelligence and a skill which is only acquired by long years of apprenticeship.

For many centuries gold has been considered the most ductile and the most malleable substance known. It is still to be considered as occupying a supreme position in these respects. But modern scientific endeavor has produced a rival at least as far as ductility is concerned. This is a special form of tungsten which is known as ductile tungsten. It is prepared from very pure metal by electrical heating and mechanical hammering in an atmosphere of hydrogen. When this progess has produced a relatively small wire, then the tungsten may be drawn through a diamond die in the open air and in this way its size may be reduced until a diameter of 0.005 mm is obtained. Such a wire is about 1/15 the average size of a human hair and it is only slightly larger than the finest gold wire ever produced. It is quite possible that further work with tungsten may produce a wire smaller than any which can be made of gold, but, at the present time, gold is still to be considered the most ductile as well as the most malleable of our metals.

What is the highest temperature that has ever been reached?

The most general method of producing moderately elevated temperatures is by burning some form of solid fuel like coal or coke in the air. Such a plan can be used to obtain a bright red temperature which will be in the vicinity of 700° C., sufficient to melt tin, lead or zinc. If a forced draft is used the temperature may be raised considerably above white heat (1200° C.), and by this means copper, nickel and iron may be melted. For higher temperatures the fuel is sometimes powdered and blown into the furnace by an air blast, thereby producing a mixture which burns rapidly, producing a temperature of about 1600° C. Such a furnace is used in the manufacture of Portland cement. If a still higher temperature is desired it may be obtained by replacing ordinary air in the blast with oxygen, thereby avoiding the cooling effect of the large proportion of nitrogen which the air contains. If a combustible gas is used with oxygen,

the highest temperatures available from a burning fuel are obtained. Thus a blast lamp burning coal gas with oxygen yields a temperature of about 2000° C., while an oxy-hydrogen flame is said to reach a temperature of 2800° C., and an oxy-acetylene flame to give temperatures up to 3500° C. The newly devised apparatus for utilizing the atomic hydrogen flame gives an intensely hot flame which can be applied to small volumes. In this way a temperature of 3800° C. can be obtained. This temperature is sufficient to melt or vaporize every known substance, with the possible exception of carbon and the new grinding material tantalum carbide.

Electric furnaces have recently come into general use for a wide variety of applications. In general these depend on the transformation of electrical energy into heat through the medium of some resistor. A wire wrapped around a core forms a furnace which may be used up to the temperature at which the metal begins to soften or react with the air or other material with which it comes in contact. Alloys of nickel and chromium are widely used for the windings, and with these temperatures in the vicinity of 1000° C. may be obtained. If molybdenum or tungsten wire is used and the hot metal is protected from air, temperatures up to 1600° C. are obtainable. If the furnace is constructed of concentric cylinders of sheet metal such as molybdenum, the inner sheet being the heat unit and the air being pumped out, a temperature of 2000° may be reached. Still higher temperatures may be obtained in an arc type of furnace in which a powerful electric current is passed through a lead of carbon granules which serve as the resistor. The furnaces in which carborundum and artificial graphite are made are of this type, and with these, temperatures of 3500° or 3600° C. are reported. This method of producing heat is very effective for certain purposes, but it is very difficult to control and is quite lacking in uniformity, a quality which is generally much desired. If the object which is to be heated is an electrical conductor it may be heated effectively in a type of furnace which is known as the induction furnace. If a high frequency current is passed around a coil which surrounds the material to be heated, eddy currents are induced which produce a rapid rise of temperature. In this manner a piece of metal may be melted quickly in an evacuated tube. The limit to the temperatures which may be produced by these devices is the temperature at which the material under treatment is vaporized. It is claimed that a temperature of about 3600° C. has been obtained in this way, but it is difficult to maintain it for any considerable time.

Recent efforts have been made to obtain much higher temperatures than can be obtained by the use of fuel or the present types of electric furnace. The principle involved in this plan consists in concentrating into one spot the sun's heat from a considerable area by means of a series of mirrors and lenses. This method has already produced a temperature of 3000°, and it seems likely that the next few years will witness the recording of temperatures which are vastly greater than any which can be produced in to-day's laboratories. This method of heating has distinct advantages in that it possesses considerable uniformity and can be transmitted through the walls of an evacuated vessel without heating the walls themselves.

The measurement of high temperatures presents an interesting study. The simplicity and general dependability of the mercury thermometer makes its use almost universal within the ordinary range. Above 500° C. some other method of measuring temperatures must be used. Advantage is taken of the fact that gases expand fairly uniformly as the temperature increases, and various gas thermometers are supplied for

use at moderately elevated temperatures. These may be filled with hydrogen, helium, nitrogen or argon, and temperatures are estimated by change in volume or pressure. Gas thermometers are both accurate and simple to operate. Electrical devices for measuring high temperatures are usually called pyrometers. They have the advantage of delicacy, adaptability and wide range, but they are usually complicated and require considerable skill in their use. There are two general types of pyrometers of this sort. Thermocouples depend upon the production of a thermoelectric force when the junction of two different metals is heated. The E.M.F. is small and so the instruments are not very sensitive. Base metals are useful for certain purposes up to about 1100° C., but generally for greater dependability and high temperatures the metals of the platinum group are selected. The second type of pyrometer depends on the increase in the electrical resistance of a wire when the temperature is raised. Platinum wire is generally used in such instruments. Skilful use of such devices gives accurate readings up to 1000° C. but temperatures as high as 1400° may be measured by these devices.

It is obvious that none of these methods of reading temperatures are usable at the extremes of the scale. For practically all readings above the melting point of platinum (1774° C.) some form of optical pyrometer is used. These are of many forms, but they all depend upon the fact that as the temperature rises the color of the emitted light changes. One successful type of optical pyrometer is so constructed that the observer sees the field divided into two parts. One part is illuminated by a standard lamp and the other by the surface whose temperature is to be measured. The instrument is so constructed that by adjusting it until the two halves are equally illuminated the temperature may be read from a scale. In another type the filament of an electric lamp is compared with the color of the surface whose temperature is to be measured. The lamp filament is heated until it disappears when viewed against the hot body; from the current required to make the filament disappear the temperature may be calculated. Such instruments may be used to excessively high temperatures, but it is difficult to obtain accurate results at such extremes of temperature.

The highest temperatures which have been sustained for a considerable time and measured with reasonable accuracy are in the neighborhood of 3500 or 3800° C. Some claims are made that still higher temperatures have been produced, but it is impossible to maintain them for any length of time or to apply them to more than a very limited area. Such temperatures seem to be very high since all known substances are either melted or vaporized by such extreme heat. However satisfied we may be in contemplating the results of scientific endeavor in this direction, these temperatures sink into insignificance when they are compared with those which we believe to exist in nature. We have good reason for believing that the interior of the earth is much warmer than the crust upon which we live. Measurements have determined that for each centimeter we descend beneath the earth's surface, the temperature rises 0.00032° C. If this rate is continued far into the earth's interior, when we reach a point which is less than 1/10 the distance to the center we will have encountered a temperature hot enough at the surface to melt or vaporize every known solid. It is doubtful, however, if such temperatures are actually realized even at the center of the earth. These extremes are startling, but the earth is cold when compared with the sun and other stars. The sun is credited with a central temperature of 40,000,000° C. At such a frightfully high temperature no solid can exist, but

everything must be in the form of a dilute gas. The density of Betelgeuse and others of the giant stars is estimated as being about 1/100th that of our own atmosphere. Consequently the temperature upon the surface of such heavenly bodies must be enormously great. It is beyond the possibility of the human mind to grasp the significance of such a temperature range. We are impressed by such comparisons with the feeble results obtained in our best scientific laboratories.

One question concerning such matters demands an answer: How are such extreme temperatures maintained? It is believed that the liberation of subatomic energy is largely responsible for this vast amount of heat energy. We know that our atoms possess a very large amount of stored-up energy but we do not know how to liberate this energy or set it at work. This is a problem for the future to solve. It is very evident that the liberation of atomic energy will provide an enormous amount of power which may be set at work to drive the machinery of civilization.

What is the most extreme cold that has ever been reached?

The production of low temperatures consists in the removal of heat by various methods. The most familiar operation in which this process is carried out is in the freezing of ice cream. The mixture to be frozen is placed in a metal can, which is surrounded by a mixture of salt and ice in a cask made of wood. As the ice melts it must absorb large quantities of heat and since the metal is a much better conductor than the wood most of the heat is absorbed from the contents of the metal can. Temperatures 20° to 25° below zero Centigrade can be obtained by salt and ice mixtures. If solid carbon dioxide in the form of dry ice is used, a temperature of near −50° is obtained, and if a volatile liquid like ether is mixed with carbon dioxide snow, temperatures as low as −77° C. result. For the production of still more intense cold, gases are first compressed which cause a rise in their temperature, then they are chilled by some of the agencies already mentioned and finally they are allowed to expand, a process which requires the absorption of considerable heat. The apparatus includes a series of concentric tubes so arranged that when a quantity of the chilled and compressed gas is allowed to escape through a valve it will expand and absorb its heat from other portions of gas like itself. Consequently each portion of the gas that escapes through the valve is a little colder than that portion which preceded it. By this method one gas after another is changed to a liquid. Liquid oxygen boils at −182.5° C., liquid nitrogen at −195.8° C. and liquid hydrogen at −252.7° C. If these extremely cold liquids are allowed to boil under low pressure, heat must again be absorbed and the liquids become still colder and may be solidified by such treatment. Of all gases helium requires the lowest temperature for its liquefaction. Liquid helium has a boiling point 268.9 degrees below the freezing point of water and solid helium is given a melting point of −272.2° C. This is the most extreme cold that has ever been recorded in a laboratory. It is to be observed that it is 0.8° above the mythical point known as the absolute zero. From a consideration of the methods employed to obtain these extremely low temperatures it is evident that an artificial temperature which is lower than the point at which all gases become solids will be extremely difficult to obtain. There are also scientific reasons which justify the conclusion that lower temperatures will be almost or quite impossible to reach by present laboratory methods. As a result of this situation the temperature of −272.2° C. is the lowest one of which we are now certain and it is possible that this will remain for many years the nearest approach to supreme cold.

Some estimates of the temperatures to be found in interplanetary space have assumed that the degree of cold which exists is many times greater than any artificial condition which can be produced upon the surface of the earth. More conservative estimates make it seem likely that these temperatures are not lower than $-150°$ C. If this estimate is at all reliable then the conditions produced in the laboratory approach much more closely to that theoretical condition which may be described as representing the entire absence of heat.

What is the most costly substance known to commerce?

The nations of the earth are so accustomed to expressing commercial values in terms of gold that the expression "it is worth its weight in gold" is used to describe objects which are priceless. In attempting to find the most costly substance it is evident that we must confine our attention to articles which are bought and sold in the open market, eliminating everything which owes its attractiveness to its artistic setting, its association as a relic, its scientific value alone or any condition which materially disturbs ordinary exchange values.

There are several materials which are worth more than their weight in gold. All six metals of the platinum group are more valuable than an equal weight of gold. Under normal conditions platinum itself is about three times as valuable as gold, while iridium, the most expensive metal of the group, is worth nearly 15 times its own weight of gold. Among the most precious materials of commerce is the diamond whose value is influenced materially by its size, color, clearness and freedom from flaws. Accepting as an approximate market value the retail price of $400 per carat, this gives the diamond a retail value of $62,500 per troy ounce. The current quotation for refined platinum is $40 per ounce, so diamonds at the present time are worth more than 1,500 times their own weight in platinum or 3,000 times their weight in gold. It is a remarkable fact that in the course of the business depression the price of diamonds as well as the quantity marketed has changed much less than other materials which are classed as luxuries. As a result of this peculiar trend in market conditions, platinum has fallen to about half its 1928 price, while diamonds have decreased only about 10 per cent.

The most costly material which is sold in the open market is radium and substitutes for radium, of which mesothorium is the most important. For many years the price of radium was in the vicinity of $100 to $120 per milligram. With the development of the wonderfully rich deposits in the Belgian Congo the price was cut to $70 per milligram. This price was evidently selected for the purpose of stifling competition, while at the same time it brings enormous profits to the producers. It has been estimated that the profits in the sale of radium at the present rate amount to well over 1,000 per cent. Such greed is difficult to understand because these huge gains are made possible only through the suffering of victims from the dread disease cancer. There is no question concerning a material relief for many cancer patients if radium were available at a more reasonable price. In spite of this fact the enormous profits are realized from the sale of radium at a price which corresponds to more than $2,000,000 per troy ounce. This means that radium is worth more than 100,000 times its weight in gold. It is by far the most precious article of commerce which we know. Second in order would be mesothorium, a material much like radium and usually sold as a substitute for radium. Its price is roughly $1,500,000 per ounce, which is sufficient to command respect even in times of marvelous prosperity.

# THE DIFFUSION OF SCIENCE[1]

## THE NATURAL SCIENCES

By Dr. ROBERT A. MILLIKAN

DIRECTOR OF THE NORMAN BRIDGE LABORATORIES, CALIFORNIA INSTITUTE OF TECHNOLOGY

*Mr. Toastmaster and gentlemen:* I take it that the purpose of this gathering is to take account of stock in an enterprise which has been under way for about eleven years with a view to seeing what can be done to improve the job that is being done. Dr. Welch a moment ago inadvertently called this enterprise Science News, but its real name is Science Service, and it is chiefly in the distinction between "Science News" and "Science Service" that I find the subject for my remarks; for the name Science Service was very carefully and very appropriately chosen with full understanding of what it meant. I will come to the explanation of the difference in just a moment, but first a word about possible types of improvement.

There are just two possible ways of improving Science Service. One is by correcting defects which may have appeared in the eleven years of its life, without altering materially its general scope and plan, and the other is by extending its activity into new fields; and what I should like to comment upon first is the reason that Science Service has thus far been limited in its activities to the natural sciences.

Twelve years ago Mr. Edward W. Scripps asked a very small group of men to come down to his hacienda near La Jolla, California, to talk with him for a couple of days about his project of devoting a certain amount of money which he had at his disposal to this purpose. The men who were there were E. W. Scripps, his son Robert Scripps (who is here to-night) and other members of the family and Drs. Ritter, Hale, Noyes and myself. Mr. E. W. Scripps outlined what he had been thinking about and I think that Robert Scripps will agree with me when I say that the prime thing that his father told us he had in mind was constructive service to humanity, not mere news gathering. He thought it was possible to move our civilization forward by some plan whereby a knowledge of the method and the results of scientific study, particularly in the fields of the social sciences, could be spread among the masses of the people. We therefore chose the name "Science Service" as embodying in the smallest possible compass exactly the idea he had in mind.

A large fraction of the first day of our conference was spent in trying to analyze the relations between the fields of the social sciences and the fields of the natural sciences, and the net result of that discussion was that we persuaded Mr. Scripps that his object would be better served if we left the field of the social sciences entirely out, at least at the beginning of the activities of Science Service, and confined its activities to the natural sciences. That may seem to some of you here to have been a narrow view-point, but stop a moment before you draw that conclusion.

What he was after was improving the conditions of human life and not the spread of news as such, *i.e.*, it was not primarily a news-disseminating service that he had in mind. It was much more fundamental than that. And the question that was then discussed was what the dissemination of scientific informa-

[1] Addresses at the Science Service dinner in Washington on April 27, 1932.

tion in any field of science, social or natural, has to give to the improvement of human life—and before we had finished we had all agreed that the great thing that it has to give is simply an understanding of the scientific method. The day is gone by when any new discovery in science, social or natural, is likely to revolutionize human life, at once, at any rate. In fact, in general, the most outstanding discoveries in the natural sciences, however useful they may ultimately prove to be, create for the time being certain difficulties, because they force mankind out of its accustomed ways of doing things, out of its accustomed organizations, and any such change in the habits of a people is attended by difficulties and readjustments, as everybody who has lived through the last three years knows full well.

The great fundamental thing that science has to give is a method, and that method has been applied most conspicuously, though by no means exclusively, in the field of the natural sciences. What we call now the objective method, or the impersonal method, or the scientific method of getting at the facts without forming any conclusions beforehand, without starting with any preconceptions as to where we are coming out—that is the thing that began to get into human life in a conspicuous and pronounced way with the advent of modern science. In a very real sense this method got started about three hundred years ago. It is this that differentiates modern knowledge from the knowledge of the ancient world, which started with certain "a priori" assumptions or assertions about the nature of reality, and tried to fit phenomena into such a general philosophic scheme. All ancient philosophy did that primarily, although I know there are some exceptions. But the thing that differentiates the modern method from either the ancient or the medieval methods is that it definitely abandons all attempts at a complete synthesis of knowledge, built up into any philosophic scheme, and starts by trying to get at definite facts, and then allows these facts themselves, with their inevitable consequences, to determine the direction in which conclusions are formed.

And I think all men who know anything about the natural sciences will be in agreement that that method, which has now come to be called the scientific method, for the reason that it started in the natural sciences, is the thing that must spread, as of course it is spreading, to all the fields of knowledge. The social sciences, if they are going to succeed at all, must of course have the same objectivity as the natural sciences. Not only that, but if we are going to have a civilization which is built up of states which are self-governing states, democracies or republics, there must be a spread of the understanding and use of that method throughout the whole of the population, for the life both of the individual and of society is completely modified by it. But it is as yet the natural sciences rather than the social sciences that lend themselves best to the demonstration of the value of this method. For in the natural sciences we have actually, up to the present time, developed a basis of non-controversial fact. In the field of physics, to take a particular illustration, any well-written text-book of the year 1890 is a perfectly good text-book for to-day. The bases of physics have not altered at all, and any text-book of physics which soundly presented the knowledge of physics as it existed in 1890 can be used without changing a word to-day. You may introduce now, if you will, the idea of an electron, which you did not introduce then, but you had then everything that was essential in the idea of electric currents, positive and negative; and the whole of the knowledge that we had in 1890 is actually the basis of our modern

physics. All of it has practically universal acceptance to-day. No good text-book writer of any period ever allows his speculations to go beyond the range of verified facts. That is why the good text-books of 1890 can be used just as well to-day as they could then.

That is also true in all the natural sciences, for each of them has its body of non-controversial fact. This is certainly true in chemistry, and future chemistry will simply build upon that base of to-day's acquired knowledge. That is true in biology, as I understand biology, and it is also true in the geological sciences.

Actually, then, the main thing that the popularization of science can contribute to the progress of the world consists in the spreading of a knowledge of the method of science to the man on the streets and in giving to the public practical demonstrations of the results of that method of approach to life's problems. The natural sciences are at present enormously better adapted to do that than are the social sciences. Take one or two illustrations from the biological sciences. The germ theory of disease, the theory of immunization, etc., these are now supported by non-controversial facts. Yet the average man scarcely knows it yet, else how could he possibly pass anti-vaccination laws and similar absurdities. But as the masses actually come to see what has come out of this scientific method, as applied to the natural sciences, I have faith to believe that their whole outlook on life and their whole mode of approach to their own problems will change. What science has got to give, then, is primarily a method; and the way that it can do that best is to make the public familiar with what that method has accomplished.

One further point about method. When we scientists present the fields of the natural sciences in public address, I think there is a technique which practically every man uses, and which too we use in all our classrooms. It is this: We outline first where we have got to-day in the development of a field of recognized knowledge, *i.e.*, in the basis of fact which is not controversial. And then we move on into the controversial fields and say: "This is a view which is held by some; and this is a view which is held by others," the point being that we always start from the things on which we can agree.

Now, when we devotees of the natural sciences talked to Mr. Scripps, we felt at that time, at any rate, that it was pretty hard to find that basis of accepted fact in the social sciences. Personally, I have always believed that there must be such a basis of non-controversial fact in the social sciences. Of course there is in the field of history. But I will say that in the last two years, when I have been trying to listen to radio talks on economics, and when I have heard my banker and economist friends talk, I have wondered where the agreement was —there are such wide differences of opinion. They do not seem to start from a common basis of recognized knowledge at all. Let me illustrate what I am trying to say as follows. If we divide a given field of knowledge, such as physics, or economics, into two parts, the non-controversial part and the controversial part; then the non-controversial part in physics is an enormously larger part or fraction of the whole than is the non-controversial part in the field of economics. In physics the controversial part will be a little fringe on this whole body of knowledge, while in economics and politics it seems to me, from hearing my economist and political friends talk, that the controversial part is here the main body, and the generally accepted part—if there be any at all—is the fringe.

Now in either field it is this controversial part in which you find what is generally called news; so that if Science Service is to become merely Science

News it will not be of very much value, for it does no good to introduce the non-technical public to the regions of knowledge in which the best informed are still wandering in a maze, as yet unable to arrive at practical conclusions. However, I should think it might be perfectly safe to expand our activities somewhat into the fields of the social sciences, provided only the men who speak on these sciences would be much more careful than many of them are now, themselves to follow the method that I have described above, *i.e.*, provided only they would arrange their material so that they can say, "All this is recognized fact to-day by economists: here only is where we differ." But after all what the public needs is that part which is recognized fact, that part upon which it can depend and which it can surely take as its own starting point. And what I need, as a physicist, in my study of the political and social sciences, is to find what is that basis of recognized fact. I confess that, as one of the masses—for in this field I am just that—I find it terribly hard to find what the recognized economists and financiers and political science specialists agree upon.

And there is another thing. As soon as we begin to make news in this controversial field we run into a very grave danger. Let me illustrate by the matter of the tariff, which everybody knows has not been handled up to the present by any scientific method. If we begin to express opinions in that field we are running a very large risk of arousing a wave of popular prejudice against this whole scientific movement and thus of undermining the whole structure upon which and for which Science Service exists. Popular psychology is a strange thing, but a thing of enormous importance, as every banker knows to-day to his sorrow. The way in which the whole financial situation of the last three months has developed—my banker friends say it is just a matter of psychology—is a warning of the dangers we might encounter in this field. Science Service could ill afford a "run on its bank." You can play with those things, but if you are not careful you may produce a wave of prejudice against the whole scientific method which may do very, very big dis-service instead of service to human progress, which is, after all, the thing that Mr. E. W. Scripps was primarily interested in.

In spite of all this I want to say that I can not believe that the social sciences will not be able to develop a basis of recognized fact; I must believe that they are going to get it in the course of time, but until they have come nearer to it than they are at present, the safer and the better way for Science Service is, I think, to stick to its last, as Dr. Keppel said this afternoon, and to do the thing that is not fraught with so much danger of getting the whole effort knocked in the head. It would be most unfortunate if we got into a social-psychological situation where prejudice would determine action. When the storm was over there might be nothing left of Science Service. These were then the reasons that we gave to ourselves and to Mr. Scripps in 1921 for not including the social sciences in our program, and they seem to me to be equally cogent to-day, though it is greatly to be hoped that they will not remain so indefinitely.

I shall then devote the remainder of my time to-night to discussing the question of what can be done in the way of rectifying defects in Science Service and in making improvements along the lines in which it has been thus far working. From what has preceded you will not be surprised to hear me say that the first thing to do is to see if we can get away a little further than we are at present from our enslavement to news, as such. Science Service has already soft-pedalled news to a certain extent. I should like

to see it go even farther. I know the public wants news, and you will of course have to give it a certain amount of frosting of that kind, but the real cake is not in the news. Dr. Abbot this afternoon struck a note which I want to repeat. Science Service has been getting out certain phonograph records. That is not a news service at all, but it is a very important scientific service. I was unfortunate enough to have to make one of those records myself. Now anybody who is obliged to talk on any subject for exactly five minutes, and to say something worth while, must obviously weigh every word that he uses; weigh it not only with reference to what he thinks he is saying, but also with reference to what this big audience that is going to listen to it thinks he is saying. What we say to the whole world is not what we say in our scientific articles to our friends, not at all. In other words, in writing for the general public it is the emphasis and the implications that count; and I am talking now not to the reporter-men who write up the news; they are not guilty. It is the scientist who needs a training along that line; and I think myself that the effect of the Victrola record and the effect of the radio broadcast is a very wholesome one for us scientists. The necessity of giving a radio speech is one of the finest and most wholesome of influences that could be exerted upon a scientific man, or upon any intellectual man. For you can not do any extemporizing before a radio microphone; you have got to have every word written and you have got also to see that your statements not only are correct but that their implications and the interpretations that the public is going to put upon them are correct, in so far as you can make them so. The most important influence that the radio has had upon modern life, in so far as the education of the masses is concerned, arises, in my judgment, from the reaction that it has upon the men who have to do the broadcasting. It is bound to make us more careful, not about what we think we say, but about what we think that our audience is going to think that we have said. We have had enough illustrations of the difference between what a man thought he said and what the public understood him to say. You men who remember the war can well remember certain phrases that got going that were meant all right but which were taken differently from what was intended. The public did not understand them in the way the man who talked them understood them.

So it seems to me that an enormous improvement in the values of Science Service can be brought about by a more careful cooperation—and I am talking mostly to the scientists—between the scientist and the man who reports for it, more care being taken by the former to put his material into better form, to see to it that the phrasing is carefully done.

To take a simple illustration. The other day I had to make a little address at the academy, and some of the newspaper men said that my "conclusions" were such-and-such with respect to neutrons and protons. I did not say anything about my conclusions being such-and-such. I stated that *the evidence* from these observed facts was favorable to a certain hypothesis rather than to another hypothesis. These two statements are quite different things—I simply said, "This is evidence on one side"; but it is a long way from presenting evidence to drawing conclusions, as much so in physics as in a court of law. The evidence must not be confused with conclusions.

One other thing that I would like to suggest as a basis for improvement. I want, if I may, to pay a little compliment to the paper (the *New York Times*), a representative of which you are going to hear in a minute, because of the fact that it takes so much pains to present so many scientific addresses

and reports in full. I do not mean to urge the printing by newspapers of long articles. There are very few of them that are worth it. We scientists write articles which no paper ought to publish in full. But if you science reporters will force your scientific man to write his own abstract; and will then quote it without rewriting it, a great step forward will be taken. I don't object to your rewriting a part of it, if only the public will understand what is your rewrite and what the author himself said, and what I myself want to see is what the man himself said. If you can get that in some short form, and if your newspapers can in general be induced to print "the words of the author," with or without your rewrite, but anyway the words of the author in just the form in which he wants them presented, I know, and every good newspaper man knows too, that you are going to get an audience that you do not get now, because there are a lot of people who want to know just what the author himself said, not what somebody said he said, not what somebody inferred that he said or wanted him to say, but what he himself said. If Science Service can do a little more of that it will take a big step forward in perfecting the humanitarian and the scientific service which it exists primarily to render.

There is one other point that I want to mention. It seems to be the effort of all news agencies to find out from scientists, not what they have done but what they are going to do, to get into their laboratories and find out what their plans are. I would like to see all that soft-pedalled, because it has no value whatever. It only annoys the scientific man. He does not want to state what he is going to do because he does not know what he is going to do. He does not want to be forced to say what he is going to do and there is not any value in it if he does yield.

Again, I want to call attention to a thing that Dr. Abbot mentioned this afternoon. Science Service is to be congratulated in that it has camouflaged under the item of news a lot of first-class stuff that has been known a hundred years or two hundred or fifty years. That is what the public ought to have. That is what the public needs, because it is a body of recognized fact that the public is ignorant about. If it were not ignorant about it, you would not have anti-vivisection or anti-vaccination campaigns. It is because the public is ignorant of the facts as to what vaccination has done that it is possible for such political tommyrot to get started as sometimes does get started in California and also in other states.

Then there is one other point. I am far from criticizing the average man who is sent by a newspaper or by Science Service to report the news. He is obliged to report the news. He has to report what we are saying. And in general you reporters do it extraordinarily well; I am often amazed at how well it is done. In fact, around our place there are a couple of reporters that I do not have to watch at all—they do it so much better than I do. They know what things are permissible and what things are not permissible and I can trust them completely. But, in general, if the reporter would be willing to sit down with the author and let the author see the way he writes up the material—and let the author OK it—it would save many mistakes. I am well aware that Science Service does this in many cases. I congratulate you on it and want to see the practice enlarged.

A few of those things would help a lot toward the improvement of Science Service.

# THE SOCIAL SCIENCES

By Dr. HAROLD G. MOULTON
PRESIDENT OF THE BROOKINGS INSTITUTE

IT has long been a favorite pastime in academic circles to discuss the relative importance of the natural and the so-called social sciences. Which is more fundamental, or basic, in character? Which has contributed more toward the upbuilding of our civilization? Which has greater significance to-day, and about which is it the more important for the public to be reliably informed?

It is not my purpose to attempt to answer these questions, for I do not think any important purpose would be served if they could be answered definitely and to the satisfaction of all concerned. I should like, however, to direct attention first to certain ways in which the natural sciences and the social sciences have reacted upon one another and how the two working together have contributed to the development of the economic system and the civilization of to-day. My emphasis at the start will thus be on the interdependence of developments in the various divisions of knowledge.

Without the discovery of certain natural laws and without the inventions based upon them the mastery which mankind has gained over nature would not, of course, have been possible. Instead of the highly developed civilization of to-day we would still have been in a stage of semi-barbarism. It is, therefore, strictly correct to say that without our achievements in the realm of natural science the epochal changes of the last hundred years would not have been possible.

It is also true that without man's capacity to devise economic, governmental and legal institutions capable of meeting the needs of a changing world, economic and social progress such as we have had would also not have been possible. At every stage in the evolution of the complex civilization of to-day the development of social machinery and institutions has facilitated and made possible advancement in natural science. I refer, of course, to the development of systems of government capable of maintaining law and order, to such legal institutions as private property and contracts, and to such economic institutions as money, credit and the corporate form of business organization. It is the development of these social institutions which has made possible the transformation of the simple economic world of the medieval era into the highly complex organization of to-day with its enormous productive capacity. Without these social institutions scientific discoveries would not have had an opportunity to bear fruit in a practical way. Thus advancement in the natural sciences has gone hand in hand with the evolution of social institutions; each is indispensable to the other.

It will be observed that in the foregoing statement I have not used the expressions "principles of social science" nor "laws of social science," but have stressed rather the development of social institutions—legal, economic and political. In this emphasis and this terminology I am giving expression to a point of view which is, I believe, essential to any adequate understanding of what the objectives of so-called social science should be, and of the importance of the dissemination of knowledge in this field to the further development of our civilization.

The fundamental concern of social science—using the term in its broader connotations—is the devising of agencies

and institutions which will bring continuous economic and social improvement, or, to use a phrase which has never been improved upon as an expression of the ultimate purposes of democracy, to promote the greatest good of the greatest number of people. We wish not only to understand the workings of the economic and social world, but we wish also to make possible its improvement.

In such a conception of social science there is obviously a place for the formulation of general laws or principles of human behavior and social progress; but not, in my judgment, a place of paramount importance.

I was very greatly interested in Dr. Millikan's statement that there has been comparatively little change in physics since 1890; and I was equally interested in his remark that he has been unable to discover, by reading certain current economic discussions of unsettled problems, any great body of doctrine upon which economists are in agreement. If Dr. Millikan had surveyed the fundamental text-books of economics in 1890 he would have found that there was a very large measure of agreement; and if he had gone back forty years further, to 1850, he would have found that there was almost complete agreement among economic students upon the basic principles of economics.

In brief, the history of the development of economics goes back to 1776, when Adam Smith first brought out his great treatise which became the foundation of political economy. There is no question that that book was conceived and written in the scientific spirit. It sought to lay down the fundamental principles that should be adopted and acted upon if we wished to promote the greatest possible wealth production for the people on this globe. That was followed by a series of treatises by English economists, culminating in 1848, when John Stuart Mill's great "Principles of Political Economy" was written. It was believed, not only by John Stuart Mill and his contemporaries but by most students of economics, in the Anglo-Saxon world at least, for the next twenty-five years that the last word on political economy had been written, that Mill's book had rounded out a body of truth built up upon the basis of certain facts and principles, or laws, as to human desires and conduct and as to the limited productive capacity of nature.

About twenty years later new light began to be thrown on certain phases of economics by a group of Austrian economists who approached certain aspects of the problem from a new angle. Then that was in due course followed by Alfred Marshall, who in 1890 brought out his fundamental treatise, which integrated the analyses of the Austrians with those who had gone before, in the English line, and showed how they could be substantially harmonized.

It was this accepted body of economic doctrine upon which economists of my generation were reared. A considerable part of this doctrine remains to-day, as any one can find by a perusal of general texts, as distinguished from the literature of controversial discussions. Nevertheless, there have been great changes in economic discussion during the last 40 years, and, as already indicated, the body of doctrine upon which there is general agreement is now smaller than was the case a generation ago. In the next stage of my discussion, I shall seek to show the forces responsible for this tendency toward unsettlement.

The change is attributable, as I see it, on the one hand to a growing body of statistical data that has given us a vast amount of factual material not hitherto available; and on the other hand to significant changes in the structure and organization of a rapidly evolving economic mechanism. It is the latter factor which I wish to discuss in the few moments at my disposal.

As a result of the economic and social evolution of modern times, we have to-day an economic system, or machine as I prefer to call it, of very great complexity and of most delicate adjustment. The managers of this system, or the drivers of the machine, are individuals who are not directly working together for a common goal but are individually in pursuit of private profits. Production will be carried on, the existing plant and equipment will be operated, and new developments will be undertaken, provided the so-called entrepreneurs can see their way to the making of a pecuniary profit. It is believed, and it has certainly been true over much of our modern history at least, that the incentive of individual gain promotes general economic progress.

This system involves large monetary outlays in the development of plant and equipment and in the production of commodities which are to be sold in the market for a financial price. If this price exceeds the monetary costs there is a profit; if not, there is a loss. In order to carry out production on the most efficient possible terms, it has been necessary to develop large aggregations of capital, and this in turn has required the evolution of the system of credit and of financial intermediaries between investors and the borrowing corporations. We have had, indeed, the development of a whole series of financial institutions which, taken together, comprise a financial system which, in turn, largely controls and organizes economic society.

This complex economic system, which tends to be world-wide in the scope of its organization and is, in consequence, handicapped by political organizations on national bases, is a most intricate mechanism. The machine never operates at theoretical maximum capacity. Measured in terms, let us say, of an eight-cylinder car, it runs on the average perhaps on the equivalent of five cylinders —sometimes operating on seven and at other times on as low as two or three.

Why is this? What forces or conditions, or perchance laws, continually impede the operation of the machine and at times produce the violent fluctuations with which we are all familiar? To find the answer to this question and to remove the cause, or varied causes, as the case may be, is as challenging, as difficult and as important a problem as is to be found in the entire realm of science. The ascertainment of the source or sources of friction and the suggestion of means for their elimination require intimate knowledge of business processes and of the working of financial and other economic institutions. The economic scientist must give the most minute study to the various parts of the complex mechanism and also to their interrelated workings. Such studies involve the assembling of all pertinent facts and also the interpretation of their significance. The method is rigorously scientific—however much the procedures may differ from those of the physical laboratories.

Now the old economics, the economics which had come to be regarded as settled, the economic "truths" of former times, had substantial validity under the conditions of a simpler age. But under the conditions that exist to-day a considerable part of these principles are no longer adequate. The economic structure has changed so rapidly that the entire problem of economic analysis has been profoundly altered. We are concerned with very rapid organic evolution.

I may perhaps best reveal how complex this problem of social science is by reference to a particular investigation with which the Brookings Institution is at the present time concerned. We have raised the question as to whether the explanation of the failure of the economic machine to operate normally at

full capacity may not perhaps be found in the way in which the wealth and income of society are distributed among the different classes of the population. The perplexing economic phenomenon with which we are all more or less familiar at present is the simultaneous existence of great unused productive capacity and an army of potential consumers who because of unemployment are without purchasing power. The dilemma may be expressed as follows: Industries can not produce at full capacity unless they can sell greatly increased quantities of goods to consumers in the market; consumers can not buy greatly increased quantities of goods unless more adequate employment and higher incomes are provided. We can not produce more until we can have more consumption; we can not have more consumption until we produce more, that is, until the consumers are furnished the purchasing power that is given to them only through the productive process itself.

An existing capacity for production greatly in excess of market demands is a state of affairs which had not been anticipated by most students of economic development. In the earlier days, during the greater part of the 150-year period since the formal study of economics began, the great problem appeared to be that of increasing production, through the building-up of capital equipment. It was believed that the consuming power would expand in direct proportion to the expansion of production, and that the greatest progress would necessarily follow from that economic system which promoted the most rapid saving and development of capital goods. It was argued that the increased supplies of capital goods would automatically decrease production costs and prices, and that the resulting increase in real wages, resulting from falling prices, would enable the masses of the people always to purchase the increased quantities of goods turned out. According to this theory, the fundamental motivating force was the expansion of capital; the increase of capital goods came first, and increased consumption automatically followed. That this result has not been fully realized is suggested by the maladjustments to which reference has already been made.

In view of this situation, we must inquire whether recent trends in the distribution of wealth and income in society may not perchance serve to retard economic progress. We are confronted with a certain body of known facts which suggests this hypothesis. What are such facts? Well, for one thing, we have found that the periods when capital expansion and growth are most rapid are precisely the times when the volume of consumption is greatest. Always a period of extravagant consumption has, according to the factual records, been a period of rapid capital expansion. Now, that suggests a possible interrelationship between expanding consumption and expanding capital creation.

We have also found that with the development of the modern corporation a very large amount of capital savings occurs automatically—through the setting aside of a portion of the income in the form of surplus and putting it back into the business. The corporation has thus been an agency which automatically results in a rate of saving much more rapid than was formerly the case.

Another element in the situation is that as society has become more wealthy we have larger groups whose incomes are in the higher brackets. Those whose incomes are in the higher brackets do not —we believe the facts will show—spend as large a percentage of their income for consumptive goods as do those whose incomes are in the lower brackets.

The question therefore arises: Are we, by virtue of the changes that have occurred in our economic system, now getting new capital, developed faster than

we are increasing the effective demand for the products of that capital? Have we thus been thrown out of balance in the rate of capital expansion as compared with the rate of purchasing power expansion in the hands of the masses of the people? We believe it is possible to find from the data available the answer to this fundamental question.

We would next inquire whether, if a larger share of the nation's annual income went to the masses of workers, both urban and rural, the resulting expansion of consumption would serve to stimulate more rapid economic growth. If this hypotheses (which we state merely as a hypothesis) should prove to be correct, then it would appear to follow that a wider diffusion of wealth and income would prove of direct benefit to all classes of society, including those in the higher income classes as well as those in the lower income classes—because the machine itself would then work more continuously near maximum capacity. By carefully analyzing the trends as to capital development for the last thirty years and the distribution of wealth and income, we hope it will prove possible to give a fairly definite answer to the fundamental issues that have been raised.

That is a problem that vitally concerns all classes of people, a problem which has arisen because of the changing organization of society. It could not have been analyzed on the basis of any facts available in a former era. It must be studied in the light of existing conditions and of the data that are now available. That the project as conceived is scientific in the best sense of that term can not be gainsaid.

Aside from these basic considerations of the working of the economic system as a whole economics, like every other general division of knowledge, is concerned with a great number of special problems, and each of these requires special study by trained investigators. We must first and foremost have intimate knowledge of facts and processes, and then we must interpret these in relation to objectives that are conceived to be socially desirable. Nearly every question that comes before our legislative bodies involves economic issues of far-reaching significance. They can be answered only in the light of accurate factual data and knowledge of economic and financial processes.

Under our system of government there is, of course, little opportunity for our legislators to be informed on the economic issues about which they have to frame legislation. This is due to many factors which are perfectly familiar to you all. It is in part attributable to lack of adequate training in economic analysis, and in part to the fact that they must constantly give heed to the ill-formed views or special interests of their constituents. Society's hope of success in solving the many problems with which it is continuously confronted thus undoubtedly rests in a very fundamental sense upon the dissemination of the results of studies in the social sciences conducted by individuals or agencies which are entirely free from political or economic coercion.

Now we have all sorts of so-called economists: we have economists for the Carpet Manufacturers' Association; we have economists for the agricultural cooperative soieties; we have economists for the Forestry Association. We have economists for the American Federation of Labor. We even have recently organized an association of "practical economists," who proceed at once to concern themselves with issues of a highly theoretical character. Those people are, however, not economists. Generally speaking, they are economic attorneys working for a special interest. I do not object in the slightest to economic attorneys. But it is a part of the problem of Science Service, if it is to carry to the public generally the results of scientific investigation, to differentiate between

those who are working in the pursuit of some special interest and those who are working on an entirely objective and independent basis. You will be interested to know, Dr. Millikan, that I was once referred to as an "objective" economist, but the individual who made the reference went on to define an objective economist as one who was in pursuit of a definite object.

Referring more specifically to Science Service, in which I have been interested for a number of years, it does seem to me possible that a certain type of information bearing on the social sciences can advantageously be disseminated through such an agency. I see no reason whatsoever why Science Service could not take any given article or any given book and say, in the first paragraph:

Here are the qualifications, training and experience of the man who wrote this book. Here are his connections. If he is connected with a labor organization, let us say that he is connected with a labor organization; if he is an economist for a lumber manufacturers association, let us say that he is an economist for a lumber manufacturers association; if he is connected with a bank, let us say that he is the economist of the X National Bank; if he is connected with a research institution or an independent organization, let us say that he is connected with that research institution or independent organization. Those are the facts about the author.

In the second paragraph there might be a succinct statement of the investigation made by this individual, the methods that he has followed, and the conclusions at which he has arrived.

The method suggested is one which would convey to the average reader certain definite information as to the conclusions reached by scientific investigators. I believe that it would promote useful thought in the mind of the average reader. I think it would give him something of the scientific spirit of which both Dr. Millikan and Dr. Welch have spoken. I would like to see Science Service experiment in the field of the social sciences. If it does not go into the social sciences sooner or later it will be evidence, not that there is not a spirit of science pervading the ranks of social scientists, but that Science Service itself lacks confidence in its own ability to sift out from the field of social science those works which are scientific in character and those subjects which lend themselves best to popular presentation. My judgment is that it will be a reflection upon Science Service in the long run if Science Service does not embrace its opportunity in the field of the social sciences.

# THE PRESS

By JOHN H. FINLEY

ASSOCIATE EDITOR OF THE NEW YORK TIMES

*Mr. Chairman and gentlemen:* Dr. Millikan is to give an address in New York, I am told, to-morrow afternoon, on the subject of "Time." I do not know what his definition of time is, or whether he speaks on standard time or daylight saving time, but those of us who are here are under the restraints of one or the other. I call your attention to the fact that it is now 12 o'clock by my time as I began to-day; and I hope that no one will feel under any constraint to stay while I finish the address which I prepared to give. I will make it as brief as I can.

I was over in Greece some years

ago. After I landed I was informed that I was to represent the colleges and universities and learned societies of America at the dedication of the Gennadius Library, which was built by the Carnegie Corporation of America, and the next morning I started to Delphi to consult the oracle as to what I should say, and I heard in my meditations this voice from the oracle, as I recall it:

Boast not of towers (for thus did Babel boast)
Nor wheels (Ixion's fate is now as then)
Nor Sisyphan statistics upwards roll—
Before your Agamemnons there were men.

But I am distressed now not so much in remembering the Agamemnons that have been as in the presence of these Agamemnons of science who are here before me. In my earlier days I might have said as Omar Khayyam:

Myself when young did eagerly frequent
The Ph.D's and heard great argument
About and about; but evermore
Came out in doubt yet wiser than I went.

As one who, once included in the class "educator," has recently become a member of that group of chroniclers and augurs of the day, observing the flight of events in all the skies of the earth, and who seems to some to have fallen, like Lucifer, from a high estate into one which has no higher place than the fourth, I venture to say a word on behalf of my fellow journalistic historians, historians of the present tense—those luciferous writers who are scattered over the earth from darkest Africa to luminous Boston, from Greenland's icy mountains to Mother India's coral strands. They are like the crustacean creatures to whom the Princeton scientist has given the name Luciferin, and so redeemed the name Lucifer from its Miltonian doom, which, though it seems a bit of fallen star dust, gives the utmost light without heat—a name that will some day be appropriate for the entire press as an agency of light without heat which only the lucifugous (those who love darkness rather than light) will shun.

Balzac has called journalism "the religion of democracy" and the journalists the priests of democracy. I do not know just what he meant—except perhaps that democracy daily turns to the press, to the newspaper, as an instrument essential to its highest functioning.

If journalists are priests, they are priests after the order of Melchisedek, that is, having "neither beginning of days nor end of life," for they live in the eternal Einsteinian present, ever on the outer verge of the "continuum." I repeated in the presence of Dr. Einstein a few weeks ago a definition of a "continuum" and, as he seemed to approve it—though I don't know whether he understood it or not—I dare to repeat it: "The continuum of events exists as a background for phenomena and when happenings occur in any region whatsoever the events are there ready to give forth their testimony."

But unless the journalist is there to hear what the events have to say, it will be buried so deep by the succeeding events that even the historian of the past is liable never to find it except with the help of the archeologist.

The true function of the historian was defined two thousand years ago by Polybius, who said that it is "to record with fidelity what was virtually said or done, no matter how commonplace it may be." That is the definition of the function of the true journalist, with a change of tense only, and with the added responsibility of giving it its setting or relationship, and to do this he goes to what is called in the newspaper office the "morgue" for his material, *i.e.*, the clippings from the newspaper of yesterday —which become the history of the imperfect past, not the perfect past, but the imperfect that comes up to him every moment of the present and goes on living

and loving and striving. The journalist is not a mere stentor but an interpreter, an all-round man of this universe of universes, whether it is expanding or contracting, running down or winding itself up.

And, as history is no longer a narrative of the doings only of kings and statesmen and prelates and generals, but reports the activities, mental and otherwise, of scientists and poets, merchants and artisans, farmers and explorers, students and vagabonds, so is journalism, the religion of democracy, all-embracing; it is the continuing revelation and record—daily, weekly, monthly or yearly—of the Almighty's continuing revision of the earth which is not complete, as the earthquakes and droughts and floods testify, and of His daily dealings with the sons of men.

I do not claim for the newspapers that they are inspired and written by holy men as of old, but merely that the best of them try to continue the objective record, news, though I think no reporters have been found quite comparable with the man who reported the Creation, and no editors who have improved on the Sermon on the Mount.

The editor's prototype is Isocrates, son of Theodorus. He was called "the old man eloquent" of his day, though he never made a speech. He wrote his speeches and circulated them on a small scale as the editor does on a larger scale to-day. Or, perhaps better, a prototype of the ancient Democritus, who, despite the range and seriousness of his thought, was called the "laughing philosopher." Here is a condensed summary of the attainments of Democritus:

> He was abreast if not in advance of the astronomy of his day, he had traversed the greatest part of the known earth, he wrote a treatise on navigation, he was learned in physics, writing on the magnet, the rays of light and the water-clock, he was fond of music and poetry, leaving works on rhythm and harmony and the beauty of epic poems, he was a critic in the matters of art, he left a book on fevers, another on prognostics, another on pestilences, another on the right of way of living, and besides wrote authoritatively on agriculture, tactics, the principles of laws, the calendar and colors, ethics and cheerfulness, besides being a zoologist, anatomist and psychologist.

But it is an even wider range than Democritus, or even Aristotle, that the modern Democritus, the editor, must have. He must not only have a glimpse into all fields of human knowledge and achievement; he must know the way to the verge in some one subject—to the place of the burning bush behind the mountain. As Charles Dana said: "He must know whether the theology of the parson is sound, whether the physiology of the doctor is genuine, and whether the law of the lawyer is good law." He must also be aware of the great abysses of human ignorance which no editorial Marcus Curtius can close, however sacrificially noble his purpose may be. He must not only know something about everything, but know where to get the everything that is known about anything.

But he must not only know, he must be able to tell what he knows or get intelligibly told what others know but can not tell. Professor Gildersleeve, the great Greek scholar, once said that there was need of academicians, but he added that they must forget their academic business if they wished to reach a wide public. He also intimated that there was certain advantage in being obliged to write at what he called finger speed, for the best words come to the front under such conditions, that is, if one has the best words to begin with. That was before the days of the typewriter. It is important to acquire, and acquire only, a vocabulary for such emergencies, and if anything is to be said for the crossword puzzles which have lately infested the press, it is this.

As an "educator" I was accustomed to divide those who could not or did not

tell the truth into three classes, not into four, as did the ancient Persian or Talmudic wisdom: First, those who do not know the truth and so if they tell it, they tell it only by accident; second, those who know it but are not willing to tell it; third, those who know and wish to tell it but do not know how.

Since I have become a journalist, I find in the observation of my fellow journalists that not even a research professor is more eager to know the truth or more eager to tell it than they—and I find too that the journalist is usually much better able to tell the truth than the research professor because he knows how to speak to the ordinary mind.

As you have already said, sir, the newspaper must know the truth, as fully as it can be known, be ready and fearless to tell it, and then know how to tell it. It is more and more to be a newspaper presenting the facts rather than opinions, and less and less an organ, but necessarily appraising news in its wholesome human values—for, as Vernon Kellogg said some time ago in an article (in *The Atlantic*, I think it was) on "Biology and Death," the biologist has to do with the species and the ordinary observer has to do with the individual. That is why, he said, the daily newspaper informs, fascinates, thrills us, while the biologist's information leaves us cold.

Dr. Keppel once called my attention to a book by a recent English essayist that put forth the theory that Nature thought to achieve the Creator's purpose by gathering as many cells as possible into one body, to be controlled by a single intelligence. But this resulted in the development of the giant lizard or the monster pig, the Dinosaur, the Baluchitherium, which perished because such mighty aggregations of cells could not adjust themselves to changed conditions or conquer them. We have now but the fossiled remains of these creatures—"fossilized failures." Then Nature set out, under divine compulsion, to reach the perfection which it sought ultimately in man, through an infinite number of individuals associated in the swarm, the flock, the herd, the tribe, the clan, the nation—may I say the League of Nations—looking toward the unity of mankind—attaining through society what the individual may not alone achieve. In that evolution the newspaper becomes a prime agent—for it can be carried forward only through the perfection of communication and interpretation.

And increasingly science's wisdom must find a place in that news, else the vast herd of human creatures may meet, metaphorically at any rate, the fate of the lemmings of Norway, swarming down to a drowning death in the sea without any plan for their journey or prospect in the event.

Scientific progress to-day is so rapid and constitutes such real news that no paper can afford to ignore its contribution to human welfare. The press once paid little attention to such gatherings as those of the American Association for the Advancement of Science and the British Association. Now the proceedings of the important scientific and engineering societies are often fully and well reported.

Several years ago I recommended for the Pulitzer prize a man whose only submitted work was his report of a meeting of the American Association for the Advancement of Science, and he got the prize. I wanted in another year to have a man get that prize who reported the lectures of Niels Bohr at Yale when he was giving six lectures there on the structure of the atom. I believe that his theory is no longer accepted, but this man reported the lectures so well that the secretary of the Franklin Institute wrote me that he had never seen published reports in a newspaper of abstract science material equal to those.

Newspapers have been irresistibly drawn into the swirl of science. Their

editors sense that extraordinary changes are taking place as the result of research and they instinctively respond. What they need is the guidance of scientifically trained staff men, for it is rarely that a paper has as its managing editor a Democritus such as the best managing editor that I have known, who was prepared when the tomb of Tut-ankh-amen was opened to enter intelligently with the archeologist, who when Einstein propounded his theory had some notion of what he was talking about, whom I found one day trying to find geometrically the area of a triangle in the terms of its sides, who in the midst of the last Presidential campaign wrote a two-column editorial on the new planet, Pluto (which I wanted at the time named Minerva, since I thought it was too bad that Venus should be left alone with all those celestial wandering gentlemen). And yet he could tell you the baseball champions for the last ten years, or the Presidential returns for the last century.

According to Dr. Austin Clark, of the Smithsonian Institution, "the number of writers for the daily press who devote their time more or less exclusively to science has increased from three or four in 1921 to between fifteen and twenty now."

Organizations like Science Service unquestionably improve newspaper standards by revealing what is real science news. And I say this not upon my own authority but that of my scientific associate. No newspaper of to-day could afford to maintain a large scientifically trained staff to range over the whole field of scientific and engineering achievement. There are, I am told, 25,000 scientific and technical journals and periodicals in which science news first appears. Even a special organization like that of Science Service can not read and digest them all. But it can digest several hundred, as it does, and thus lighten the tasks of the newspaper editor.

From the other side, that is, from the side of the scientist, there has been a distinct change in the attitude of scientific men to the newspaper. Once they despised its efforts at popularization. Now they realize how necessary the newspaper is if science is to have any popular cultural value. We even find the American Institute of Physics established by a group of research scientists for the primary purpose of aiding the press to present the facts of physics simply and clearly. The engineering societies also have their publicity bureaus. The amount of scientific and engineering information sent to the *New York Times*—again I am told this by my scientific associate—spontaneously is enough to fill at least two pages daily.

I have but in the most general way suggested the opportunities and obligations and the service of the press as a medium for the distribution of scientific information. So far as science can speak with an authoritative voice and in language intelligible to the lay audience, the press will be its eager interpreter. (And I may say that a reporter never has any opinion; he simply reports the news and the editor is the interpreter.) It is confused at times by diametric views, such as those of the expanding and shrinking universe, but when science speaks with certitude and clearness, the press will become its amplifier to the eyes of the multitude and will even assist in the social and economic miracle of multiplying the loaves and the fishes for the hungry and saving life.

The best answer to those who find fault with our product in the present tense is given by a recent historian of the newspaper, Miss Lucy Salmon, who has said:

> With all its inaccuracies, its lack of proportion, its many temptations—not always resisted—to throw prismatic colors instead of the white light of truth on its accounts of the day, the periodical press still remains the most important single source that the historian has at his

command for the reconstruction of the life of the last three centuries.

And if for the last three centuries, why not for the passing day?

Mr. Justice Holmes once said in a letter to a friend of mine that we "no longer look to the past for our sanctions. A fashion in hats goes around the earth in six months and is forgotten in a year." We shall come to glory, he added, "not in immortality, but in illocality."

The press is the chief agency of illocality, assisted by those swift, modern mercuries of automobility and telepublicity, in this televictorian age, as I have often called it—the age of the telegraph and the telephone, the tele-radio and television, and above all the tele-printed word.

If we are to find and spread the best that anywhere comes to be in the present, those who are selected for this high service, as I have said, must know how to tell the truth, and they have to do it with words, in cold type. Dr. Samuel Johnson, the editor of the famous dictionary, quoting some one before him, said that he was not so lost in lexicography as not to know that words were only the daughters of men while deeds were the sons of Heaven. But, after all, it is only by the daughters of men that the sons of Heaven get born. In the "Terrible Meek," by Charles Rann Kennedy, the dramatist presents a scene in which a cross is dimly seen in the background and in the foreground an English Tommy and an English Captain are shown in conversation. The Tommy is saying that it is too bad that one should come to this just for the saying of a few words, "Words, words," said the Captain, "words are the most powerful things in the world. All the good or bad that gets done in the world is done by words." Truly, "in the beginning was the word," but it will be with man to the end of time, that is, until God stops speaking to men, until the reporter journalist has filed his last copy and the editor has made his last comment, until the last edition has gone to press and Gabriel's trump has been heard by radio around the world.

# THE NEW CONCEPTION OF MATTER IN MOTION

By Dr. THOMAS H. JOHNSON

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THE physical world is like a puppet stage upon which we see the various phenomena of nature. The stars, the sea, the minerals of the earth, the living plants and animals and the products of our industries—these and the devices of the physical laboratory are the visible actors whose actions are controlled from behind the scenes by some secret mechanism. It is the guessing game of the natural philosopher to try to imagine what this mechanism is and how it operates.

Whereas men have been pondering over this riddle since the dawn of civilization, it is only within comparatively recent times that any real progress has been made in its solution, and though still very far from being completely unraveled, the marvelous success of the atomic theory in fitting together large blocks of the puzzle indicates that therein lies a clue to a general understanding of a large class of natural phenomena. The suggestion that matter is composed of indivisible particles or atoms dates back to the ancient Greeks, although in their hands it failed as a useful physical theory to account in detail for any of the observed properties of matter. In the middle of the nineteenth century the idea was again revived, and, at this time, it was developed into what is now known as the kinetic theory of gases.

According to the concepts of this theory, a glass tube filled with a gas under the pressure of the atmosphere is in reality the scene of an excited mob of similar atoms, rushing at each other with faster-than-rifle-bullet speeds, colliding with the walls of the vessel, each being jostled about by the onrushes of the others, and presenting to the eye of the imagination a scene far more wild and disorganized than the sea of taxicabs in Times Square on a Saturday night. The theory tells us that each atom is a tiny sphere only a few hundred-millionths of a centimeter in diameter; that it can travel, on the average, a distance of ten to one hundred times its diameter before colliding with another atom; that, in spite of the fact that one cubic centimeter of the gas contains atoms more numerous than the blades of grass on a huge putting green the size of all the territory east of the Mississippi River, their combined volume is only about one hundred-thousandth of the cubical contents of the containing vessel.

It would be impossible in this short article to enter into all the steps in the development of the theory of the atomic constitution of matter, but two observations will indicate how well the theory is in accord with experimental facts. If the spray from an atomizer is examined under a high-powered microscope the small drops of liquid floating in the air may be seen to dance about on highly irregular paths, darting first this way, and then that. Its motion may be compared with that of a football hero who is being tossed on the hands of a mob of admiring students. In much the same way the droplet is being knocked on all sides by the impacts of the atoms of the air, and since these are of finite size and number, it is a matter of chance that at times the drop will be bumped with more force on one side than on the other. The motions of the drop, produced by the im-

pacts of the atoms, are, in fact, a visible epitome of the motions of one of the atoms, the velocity and range being reduced in proportion to the greater mass of the drop.

Even more conclusive evidence than this for the atomic constitution of matter may be seen when the rays from radium are allowed to pass through an atmosphere supersaturated with water vapor. Under these conditions the rays produce a condensation along their path in the form of a visible thread-like cloud very much like the line of smoke left by a "tracer" bullet. These rays, shot out like the bullets from a machine gun, can be collected in a glass vessel, and, in their quiescent state, they constitute a gas which can be recognized as ordinary helium. Here, then, we have a vivid picture of helium atoms shot out from the radium, one at a time, and in their aggregate producing a familiar form of matter.

These are but two illustrations of facts which more obviously demand the atomic theory in their explanation. There are numerous other instances where the success of the theory has been equally great, not only in giving a qualitative explanation of the phenomena in question but in yielding precise numerical values which agree with such measurable quantities as the pressure of a gas, or the rate at which it flows through a tube. So extensive are these applications of the atomic theory that we may regard it as a proven fact that atoms exist, and that they play as important rôles behind the scenes of nature's theatrical performance as do the strings and levers in any puppet show.

Remarkable as these discoveries may seem, they are but surface scratches when compared with the deeper diggings into nature's secrets which the past two decades have witnessed. If a gas is stimulated by the heat of a flame or by the passage through it of an electrical discharge, it will emit light of various colors. This light is the voice of the atom, and the modern physicist has learned to understand its language. Just as the paleontologist reconstructs the animals of a million years ago from a few remaining bones, so the physicist reconstructs the atom from the colors of its light. The methods of the physical laboratory are capable of distinguishing between approximately four million different colors, and of these the hydrogen atom, as an example, emits only about one hundred. What a stupendous achievement of the mind it is that theoretical physicists have been able to construct in the imagination a mechanism which will emit exactly these one hundred colors and no others. A still more remarkable aspect of the situation is the fact that the mechanism which has been constructed to explain the atom's light also contains the properties necessary to explain such facts as the atom's tendency to unite with other atoms in the formation of chemical compounds, or to explain the distances at which atoms are separated when packed together in a crystal. Such confirmations of the theory as these give us confidence that the atom is as well known as any of the large-scale objects with which we are familiar in every-day life.

Of the ninety-two different kinds of atoms found in the earth's crust, the simplest is that of hydrogen. It contains a central nucleus which carries all but one two thousandth of the total mass of the atom and a charge of positive electricity equal to about one per cent. of the smallest charge required to affect our most sensitive charge-measuring instruments. Circulating about the nucleus is an electron bearing the small remaining fraction of the atom's mass and a charge of negative electricity equal in amount to the positive charge of the nucleus. The exact path described by the electron has apparently no way of making itself known to us, but its average distribution in the space about the nucleus may be

pictured from the accompanying figures (Fig. 1, A, B and C) constructed from the theory by Dr. H. E. White, of the University of California. These show the hydrogen atom in several of its various states, transitions between any two of which result in the emission of one of the colors in the hydrogen spectrum. It is this special distribution of the electron during the course of its rapid wandering about the nucleus which determines the diameter of the atom, for it is known that the outer boundary of this electron cloud is impervious to the approach of other atoms. So complete, in fact, is our knowledge of the atom that we might even calculate to what extent one atom would dent another if the two were dashed together with some known velocity. In short, we may think of the atom as a corpuscle having as definite properties as any ball which we can take in our hands and examine.

It is of interest to inquire about the rules which govern the motions of these atom balls through space. Just as it is necessary to know something about the motor vehicle laws to understand the procession of automobiles on the public highway, so our knowledge of the structure of the atom must be supplemented by a familiarity with its laws of motion if we are to understand the phenomena of nature in terms of the underlying atomic processes. What, if anything, can be said in general about the motions of these tiny corpuscles? Is there some rule, common to all atoms, by which we may know where they may be found in space at any predetermined instant and, if so, what initial information is necessary to supplement this rule in order that such a prediction can be made?

This is the problem which confronted Sir Isaac Newton in the case of the motions of the planets. The acceleration or the rate at which these bodies change their velocity, he discovered, is a quantity which depends upon the position of the body in space relative to other bodies, and it is independent of the velocity with which the body is already moving. As an illustration we may think of a shower of meteorites falling towards the earth with various velocities. If, at a distance one thousand miles above the earth's surface, one of these meteorites, already moving with a velocity of 30,000 feet per second, should increase its velocity during one second of its fall to 30,020 feet per second, Newton found that the general law of motion was such that another meteorite with a velocity of 20,000 feet per second at the same place would, in the same length of time be expected to increase its velocity to 20,020 feet per second. The change in velocity per second would be the same for all bodies at that place regardless of the velocity already possessed. This rule of motion lies at the base of a deterministic view of the world, for, by its use, one need only be familiar with the unchanging properties of space through which a body may travel in order to be able to calculate from the position and velocity of the body at some particular instant where it was at all past times and where it will be at all future times, and to compute the corresponding velocities. In other words, a body's complete history, both past and future, may be written if its present state is known. Since the question of determinism has always been a debatable point in philosophy, one now realizes from another aspect the importance of a knowledge of the laws of motion of the atom. It is, of course, to be realized that the exact condition of any large-sized object is completely determined by the positions and velocities of its constituent atoms and if these are completely determined by the positions and velocities at some previous time, one can scarcely avoid the deterministic view of the world.

But *is* it possible to predict the motion of an atom by means of Newton's law or by some other law so that once its position and velocity are known its position

and velocity throughout all time may be determined? If such is the case it should be possible in principle, even though too difficult in practice, to observe the positions and velocities of all the atoms in the world to-day and then to calculate where they were and how fast they were moving a million years ago or a million years hence. In fact, the entire history of the world, accurate to the most minute detail, would be contained in its present state, if some such rule holds true. But the answer which experiment gives to this question is, "No, there is no rule by means of which one can make such a prediction from any present knowledge of the atom."

The situation may be illustrated by an analogous state of affairs long known to exist in the case of the motions of the corpuscular rays of light. Although the failure to find such a rule in this case led scientists for nearly a century to give up the idea that light is of a corpuscular nature, now that its corpuscular properties have been firmly established, the situation may be described as though this fact were recognized from the beginning, as is the case with the atom.

Exactly how does the Newtonian rule fail to describe the motion of a light corpuscle? The trouble may be illustrated by thinking of a simple experiment. Let us imagine three points, A, B and C, all on the same straight line, and let us suppose we know that a light corpuscle has passed through the points A and B and has arrived at C. This corpuscle has served to explore the space along the line of its path so that Newton's law may now be applied to a second light corpuscle which passes through the points A and B. Since the first corpuscle was undeflected from the straight line, the properties of the space are such that between the points A, B and C, one light corpuscle has gained no sidewise component of velocity. Newton's rule states that the gaining of velocity is a property of space, the same for all similar corpuscles and hence it should follow, if his rule applies, that the second light corpuscle will also arrive undeviated at C. This experiment was first carried out in 1821 by Thomas Young. Fine apertures were placed at the points A and B and a screen contained the point C. If the Newtonian law were true, the spot of light formed at C should have remained sharply defined and have become narrower and narrower as the apertures at A and B were made smaller and smaller, for the law demands that all corpuscles describe identical paths to within the angular aperture of the two diaphragms A and B. The result found, however, was that similar corpuscles did not follow identical paths to within this angle and the beam at C was broadened beyond the aperture of the slits. In fact, after the slits were narrowed beyond a certain amount the beam became broader and broader. The Newtonian rule, therefore, did not apply to light corpuscles under these conditions of motion, and some other formulation of the law of motion of the light corpuscle was necessary. For this purpose the classical wave theory of light was developed.

Although the philosophical view of this theory has changed from time to time, the present aspect, based upon the experimental proof of the existence of the light corpuscle, is somewhat as follows. If a single light corpuscle emanates from a fine hole and passes through a system of apertures, prisms, lenses, mirrors and what not, and falls upon a screen, we can make no definite prediction as to just where it will hit. The most that we can predict are the relative numbers which will fall on the various parts of the screen in case a large number of such corpuscles emanates from the hole and this prediction is carried out, not by Newton's rule, but by the use of the following artifice. A wave disturbance is imagined to pass through the hole with a definite rate of propagation

at each point in space. The wave-length of this disturbance must be imagined to be inversely proportional to the momentum (mass times velocity) of the corpuscle, and its intensity in front of the hole must be proportional to the number of corpuscles emerging per second. We must next imagine this wave to be propagated through space according to the well-known laws of wave motion and to appear with calculable intensities over the entire area of the screen. Apparently, what we can say about the corpuscle then is that the relative numbers appearing at the various points on the screen are proportional to the intensities of the imaginary wave disturbance at these points, but, beyond this, no prediction can be made about the path followed by any particular corpuscle. It is as though we were to describe the motion of a ship in the following mysterious way. If the ship were scheduled to leave New York Harbor at some definite time and we should attempt to predict its appearance in some other harbor at a later time, we would have to realize that uncertainties existed which made an exact prediction impossible and all that could be done would be to state the relative chances of its appearance in each of the harbors of the world. This prediction would be carried out in the following artificial way. At the time the ship was scheduled to leave the harbor a wave would be started by exploding a charge of dynamite under the ship's keel and this wave would propagate itself across the ocean and produce disturbances in all the ports of the world at later times of intensities which could be calculated from a knowledge of the original disturbance and the characteristics of the shore, the latter coming in to take account of reflections and slower rates of propagation in shallow waters. The chance of finding the ship in any port at any time would then be proportional to the intensity of the wave disturbance there. If the ship were a light corpuscle, something like this, it seems, would be the best that we could do about predicting its movements.

It was stated above that the corpuscular character of light has been firmly established experimentally. In a sense this is true, but really all that we know of the light corpuscle is based upon the fact that an electron, when affected by light, behaves as though it had experienced a blow from a corpuscular entity of a definite energy and momentum. Besides this fact, we actually have no knowledge of such properties as the size, mass or internal structure of the light corpuscle. Could it be possible that the failure of Newton's law to apply to the motion of light is after all due to a misconception of its true nature and, though light does seem to be able to deal corpuscular blows, it is really of an entirely different character and is not to be thought of as a shower of corpuscles?

Thoughts such as these need not annoy us at this stage of our knowledge, for similar difficulties have appeared in applying Newton's law to other corpuscular entities. The electron, besides sharing the corpuscular behavior of light, also carries a corpuscular charge and the atom is an entity as corpuscular as a baseball, the only pertinent difference being that it is one hundred million-million-million-million times lighter, and yet these entities of more distinct corpuscular characters are just as illusive as the light corpuscle in not allowing us to know exactly where they may roam. The trouble is obviously not with the corpuscular concept but with the laws of motion of the corpuscles. In fact, the motions of all these corpuscles must also be described by a wave artifice.

This fact, first suggested in 1923 by de Broglie, has been confirmed experimentally by the now famous experiments of Davisson and Germer, in the case of the electron; and in the case of the atom, by the recent experiments of Estermann and Stern and those of the author.

A simple experiment for testing the applicability of Newton's law with two slits and a screen has already been described. This method, which was the first to reveal the wave character of the motions of the light corpuscle, could have been used also with the atom or the electron, but it has the practical drawback that it is exceedingly difficult to construct a slit fine enough to produce an appreciable broadening of a beam of either of these entities. It is a characteristic of the wave description of the motion of a corpuscle that a deviation from the Newtonian description, for example, a broadening of the beam, in the slit experiment, occurs only if the wave-length of the imaginary wave is comparable or longer than the dimensions of the slit. In the case of visible light this wave-length is about five ten-thousandths of a centimeter but in the case of a beam of atoms moving with the velocities which occur in a gas at ordinary temperatures the wave-length is another ten thousand times smaller and hence it is almost beyond the limits of the finest machine shop practice to construct a slit that is narrow enough to produce a broadening of as much as one degree beyond the angular aperture of the slits themselves.

As it often happens in experimental science, when man fails, nature lends a helping hand and in this case an almost ideal piece of equipment may be found in nature's stockroom. The surface of a crystal, being made up of an array of similar and regularly spaced atoms, in fact, constitutes an array of slits of just the width needed. When an atom beam falls upon a crystal surface the atoms of the crystal are good reflectors, whereas the interstices between the atoms are poor reflectors. The atoms themselves then are the slits. The fact that they reflect rather than transmit fortunately introduces no important differences into the argument. There is, however, one difference between the experiment of reflecting an atom beam from a whole array of tiny mirrors and that of reflecting the beam from just one mirror, the latter experiment being the exact equivalent of the slit experiment already described. The difference, however, is one which has long been known to the physicist, for just such arrays of tiny mirrors as those constituting the surface of a crystal have been constructed for many years on the ten thousand times larger scale for studying the waves of light.

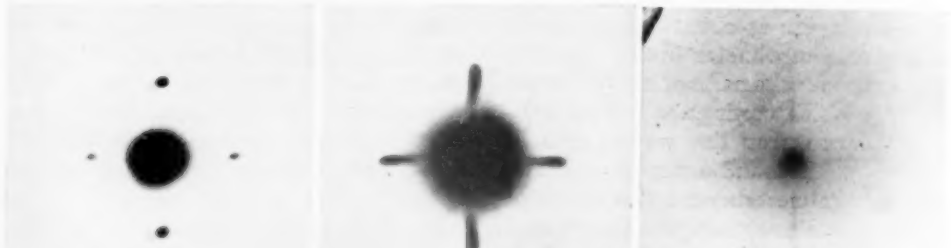
A discussion of the effect of the array on the broadening of a beam of waves would take us further into the theory of waves than is necessary for the purposes of this article, and it will suffice to state that the broadened bundle of rays from an array of mirrors includes as wide an angle as the rays from a single mirror of the size of just one of the mirrors in

FIG. 1. PHOTOGRAPHIC MODELS OF THE HYDROGEN ATOM IN THREE OF ITS MANY POSSIBLE STATES, CONSTRUCTED ACCORDING TO THE MODERN THEORY BY DR. H. E. WHITE.

the array. There is, however, the difference that the single mirror sends rays into all the possible directions included within this bundle, whereas the array of mirrors sends rays into only a few of these directions. The interesting and instructive fact about the array is that the directions which it selects out of all the possible ones are related in a very definite and simple way to the wave-length. For this reason, the crystal experiment allows us not only to prove that the motion of a beam of atoms must be described by a wave artifice, but it enables us to measure the exact wave-length of the waves. The results, as we shall see, happen to have rather far-reaching philosophical consequences.

Instead of going further into the description of what is to be expected if an atom beam behaves as a wave when reflected from a crystal, it is more convenient to call attention to the pattern shown in Fig. 2a, which is a photograph of what appears on a screen when a beam of light of some definite color is reflected from an artificially constructed array of mirrors, each mirror being five ten-thousandths of a centimeter on a side. If some other color or wave-length were reflected from the same array, the number of these beams would be the same, but their positions would shift along the lines drawn to the center of the pattern. The pattern produced by white light, that is to say, light of a continuous range of wave-lengths, therefore, consists of a continuous series of such spots overlapping along these radial lines. Such a pattern is shown in Fig. 2b.

The motion of the light corpuscle, we know, requires for its description the wave artifice if these patterns are to be explained. The proof that the motion of the atom follows the same type of law now rests upon the similarity between the pattern of Fig. 2b and that of Fig. 2c, the latter being the pattern which appears on a screen which receives atoms which have been reflected from a crystal surface. The correspondence between the two patterns is complete and it shows that Newton's law is no more adequate for the description of these newly discovered motions of the atomic corpuscle than for the old familiar vagarious paths of light.



(*a*) (*b*) (*c*)

FIG. 2. (*a*) THE PATTERN FORMED BY LIGHT OF ONE COLOR WHEN REFLECTED FROM AN ARRAY OF MINUTE MIRRORS. (*b*) THE PATTERN FORMED BY LIGHT OF MANY COLORS WHEN REFLECTED FROM THE SAME ARRAY OF MIRRORS. (*c*) THE PATTERN FORMED BY HYDROGEN ATOMS OF MANY VELOCITIES REFLECTED FROM THE ARRAY OF MIRRORS COMPOSED OF THE INDIVIDUAL ATOMS ON THE FACE OF A CRYSTAL OF LITHIUM FLUORIDE.

Why is it that the atom's motion defies exact description according to the Newtonian law when larger corpuscles such as a marble appear to follow this law exactly? The answer can be learned from the experiment, for by a study of the distribution of intensity along the

arms of the pattern in Fig. 2c, a relation is found between the wave-length and the momentum of the atom. This, in fact, turns out to be just that predicted by deBroglie, *i.e.*,

$$\text{Wave length} = h \div (\text{momentum})$$

where h is a constant having the value $6 \times 10^{-27}$ in the centimeter- gram- second system of units.

If this same relation is applied to the motion of a marble, its wave-length turns out to be so small compared with the width of any slit through which the marble would pass that it would be impossible to detect any uncertainty in its direction to within the minute angle subtended by the width of a hair at the distance of the most remote spiral nebulum.

Perhaps the most remarkable aspect of the newly discovered laws of atomic and electronic motions is the fact that it is now possible to include all motion under one law; the same for light corpuscles, electrons, atoms or large-sized objects. Everything is guided by a wave whose wave-length is related to the momentum of the corpuscle by the mysterious constant h, the Newtonian law now appearing as an approximation, though a very good one in the case of the objects of our ordinary experience, to the more general and fundamental wave law. A unification of this kind is, of course, very satisfying, for it leads us to believe that our knowledge of all types of motion is now complete.

Whenever some new law of nature is discovered it is a most natural question to ask, "To what use for the benefit of humanity can the new knowledge be put?" In fact, man is perhaps even more interested in trying to put natural forces to some useful purpose than he is in trying to understand them. Will it be of any use to humanity to know the laws of motion of the atom? To answer this question one need only recall the passive state in which the science of engineering lay up to the time Newton learned to understand the laws of motion of large-sized objects and then to note the great difference this knowledge made in man's ability to help himself with all kinds of machinery. May it not be possible that the 250 years following the discovery of the fundamental laws of atomic motions will witness as great a development in man's control over the atom as the last 250 years since Newton have witnessed in the development of man's control over the machine. In fact, the new knowledge is already laying a theoretical foundation to the science of chemistry which can scarcely avoid leading to new and beneficial developments. The formation of compounds or alloys having any desired physical properties, predictable in advance, is just one of the results to which this science may lead. Since all material substance is made up of atoms, a thorough understanding of the atom should lead to an understanding of all forms of matter.

# THE EXPOSITION OF SCIENCE[1]

By Professor HENRY CREW

PROFESSOR OF PHYSICS, NORTHWESTERN UNIVERSITY AND CHIEF OF THE DIVISION OF BASIC SCIENCES AT THE CENTURY OF PROGRESS EXPOSITION

AN eminent man of letters, an Englishman, has recently likened modern science to a rich uncle who has brought to the nursery more toys than the children know what to do with. Mr. Wells might have gone further and added that, as the panorama of life becomes more complex and more mysterious in this nursery occupied by us "children of a larger growth," the need for analysis and brief summary becomes more urgent. Were I to say that such an epitome of what we have learned may be obtained by conversation, by reading, by expository lectures, by scientific exhibitions and by experiment, you might infer that the exposition of science appears to me an easy problem; but I want to assure you that quite the reverse is true. If I were to confess to you that I have been engaged continuously for forty-five years in the exposition of science, you might think that I know something about the subject; but I want to assure you that quite the reverse is true. The exposition of science is a subject which appals me by its complexity, and I am still wondering how I ever came to promise Dr. Cattell that I would speak here upon this topic; for the subject is one upon which I have had no leisure to read, and small liberty to experiment. My only apology must be, I fear, that I have enjoyed a fairly long period of observation. Accordingly, the most I can do is to share with you some of my observations.

First, and incidentally, I have observed that differences of judgment in men result most frequently, not from differences in method of reasoning but from differences in definitions and from difference in premises assumed. Let us, therefore, at the outset, agree if possible, upon the definitions of the two words, "exposition" and "science." The first of these is employed very nearly in its literal sense which is merely the setting forth, the placing of an object or subject out in front where it may be seen and grasped by all. We may safely assume universal agreement as to the meaning of "exposition," in spite of the fact that the New English Dictionary gives eleven different definitions.

When, however, it comes to "science," the matter is quite otherwise. Here the great Oxford compendium gives us more than a dozen different senses in which the word is employed. Usage is, indeed, so diverse that one feels almost like saying that each man must make his own definition before he begins to speak. On the other hand, there is, I imagine, in this particular group, that is to say in this Association, more unanimity in the use of the word "science" than in any other group of equal size in America.

To put the matter in another way, what is the thing in whose advancement this Association is particularly interested? Is there, indeed, any one thing which we have in mind when we foregather, as here in Syracuse, and speak of science? This latter question must, I fear, be answered in the negative. At least I feel pretty certain that no single definition can be framed that will satisfy all my friends. To define anything is to

[1] An evening lecture before the American Association for the Advancement of Science at its Syracuse meeting, June 24, 1932.

draw a boundary which shall include all that thing and exclude all which is not that thing. In attempting to describe the best usage, I would be inclined to say that the field of science includes all the phenomena which men have observed and correlated; but of course, with the understanding that the observer is a normal individual and that the phenomena are such as can be observed by other normal individuals.

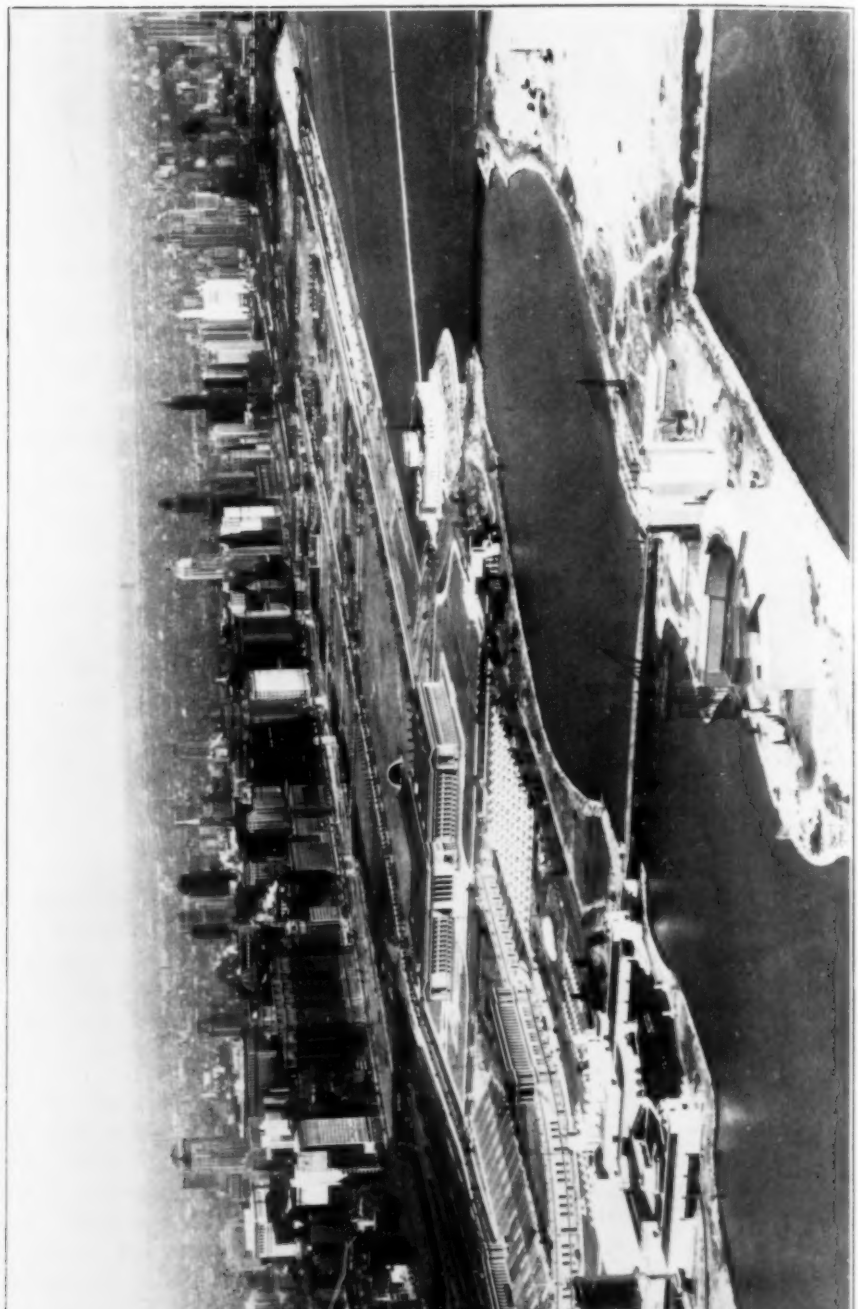
If, however, the range of science be limited to phenomena, the question at once arises as to what is to be done with human purposes, as these express themselves in, say, literature, history and politics? Where is one to classify the assumptions of mathematics and the art of drawing correct conclusions from these assumptions? So far from placing this discipline outside the pale of science, there is a general feeling that mathematics, although mainly deductive, is an ideal science; what Münsterberg called a normative science. Mathematics and logic describe, in a certain sense, our experience as to how the normal mind works in arriving at correct judgments.

The best formulation of this restricted definition of science that I have seen is the one given by Professor Herbert Dingle, the well-known English astronomer, in a charming little volume, which appeared last year, called "Science and Human Experience," where science is defined as "the recording, augmentation and rational correlation of those elements of our experience which are actually or potentially common to all normal people."

Here is a definition which is wide enough to include mathematics at one end of the series, with psychology and anthropology at the other end; and narrow enough to exclude literature, history, politics, religion and all matters of taste where experience is no longer common to you and to me. Dingle's formulation is restrictive: it excludes the whole group of what Münsterberg calls the "Historical Sciences;" But it describes very perfectly, I feel, just what our Association is attempting to advance. It includes what we all call the natural sciences and excludes what Dr. Cattell calls the unnatural "sciences," namely, politics, economics and sociology. Furthermore, this definition implies just what is understood by scientific method. This is the science which has aided industry, the science which has given us increased leisure even to the point where a reduction of leisure would bring an increase of happiness to several millions of our fellow citizens.

### The Systematic Exposition of Science

Using science in exactly the sense in which Professor Dingle has employed it, let us compare for a moment some of the fundamental modes of its exposition. One who has noted the tender age at which an infant, having dropped a toy, will learn, not to direct his gaze all around the room, but to look toward the floor; or one who has witnessed the surprise of a little child when a piece of ice melts and disappears in the warm grasp of his small hand; or one who has observed the promptness with which this same child learns to steer clear of a hot stove, is not likely to under-estimate the efficiency of the experimental method of acquiring knowledge. The three examples which I have just cited might perhaps be called independent investigation, rather than exposition. When, however, this same child becomes old enough to ask his father questions, or when he comes to his mother for explanation of how this, that and the other thing works, and when the intelligent parent answers the child's inquiry by a practical demonstration before his eyes, one has the exposition of science at its very best; native curiosity satisfied by



GENERAL VIEW OF THE EXPOSITION GROUNDS,

*Courtesy of the Chicago Aerial Survey Co.*

JULY 1, 1932. ELECTRICAL BUILDING IS THE CENTER OF THE FOREGROUND.

immediate observation, experiment and conversation; a word of suggestion rather than complete analysis is often all that the parent has time to give; and this slight stimulation is, perhaps, the most perfect form of instruction.

In high school and college, all but a few first-class minds are likely to become slaves to the text-book, more interested in examinations than in the subject; the edge of native curiosity is likely to be dulled; mathematical formulae are likely to be substituted for good common sense. The experimental lecture helps to some extent, especially if there is plenty of give-and-take across the demonstration table. The longer one's experience with America's experiment of educating all grades of minds in the same class, the more keenly he realizes the dangers of a college course and the more clearly he grasps the point of the old proverb that "Truth can be expressed only in the form of dialogue."

Coming to graduate work, that is to graduate work properly so-called, one meets again the contact of mind with mind, the indispensable personal element, and the individual private study which make the exposition of science to eager, gifted, advanced students tremendously effective and productive. In all that I have said about the dangers connected with the exposition of science as one meets it in college, there is not the slightest derogation of the student himself. For, of all the various groups that make up the modern university, the young people who fill the freshman seats are doubtless the least spoiled, the most sincere and the most straightforward. No man whose imagination has not atrophied can ever stand before a college class without thinking that these are the men who twenty years hence will be running the world, with the chances all in favor of their running it a little better than those at present in charge.

### The Popular Exposition of Science

Leaving now the systematic presentation of science, which begins in the home, carries on through the schools, and is eagerly sought throughout life by men of science, we pass to the problem of offering science to the public, a problem which assumes new importance in view of the fact that the very existence of the human race appears to depend upon our ability to adapt ourselves to the innovations of science and to the new environment which science has created. Indeed, it is not unlikely that, before the end of this century, science will play a rôle quite as dominating as that of the church during the thirteenth century.

That the popular exposition of science is a duty which workers in science owe to the public is manifest from the fact that the public is now the principal patron of science. There is no servility connected with such an exposition. It is no longer necessary for a distinguished scholar, such as Daniel Bernoulli, to dedicate his work to "your highness, most serene and most gracious lord" and then sign himself as he does in his great treatise on hydrodynamics, "Humillimus et obsequiosissimus servus, Daniel Bernoulli." The individuals who patronize science to-day generally do it through public institutions, such as the Rockefeller Foundation, the Carnegie Institution or an important university such as that in which we are now assembled.

### Newspapers

One would naturally think that the best way to transmit the rather technical results of science to the public would be first to translate these results into clear and simple English and then leave the rest to the daily press. If, however, any one thinks that a newspaper would gladly use such material to fill the space that is left over, after the advertise-

GENERAL VIEW OF THE EXPOSITION GROUNDS, *Courtesy of the Chicago Aerial Survey Co.*
JULY 1, 1932. ELEVATION OF BUILDINGS IN THE CENTER OF THE EXPOSITION.

*Courtesy of the Chicago Aerial Survey Co.*

THE HALL OF SCIENCE,
JUNE, 1932. ARCHITECT, MR. PAUL CRET.

ments have been taken care of, he is doomed to disappointment. "Clear and simple English" is not sufficient. Newspapers differ, of course; and there are exceptions to all rules; but in general an article on science must be "jazzed up" in order to be acceptable. The style must be interesting; the results striking. This means that the evidence upon which a result depends is frequently omitted; there is little distinction drawn between inference and experimental fact; figures are often used to give an external appearance of precision, while in fact the first essentials of accuracy are wanting. I fear I am almost alone in thinking that the same American public, which so enjoys the solution of crossword puzzles, would also enjoy unravelling the argument for many an important laboratory result in biology or physics, if only the sequence were presented in such a way that each statement hinges upon those which precede it. There is so much new material constantly appearing and so many old results unknown to the public that there never can be any dearth of news for any paper which desires to print a column of science in each issue.

The crying need in the exposition of science by the daily press is first of all a higher regard for the exact truth and a recognition of the fact that accuracy is the first step toward morality. The second need is that men of science should cultivate a more artistic and more logical presentation of the truth.

### International Expositions

Coming now to international expositions, which is the restricted topic upon which I was invited to speak, one finds here a method of presenting science which has new possibilities, because it is purely voluntary; it requires no examinations, not even reading; it touches only the high points; it stimulates by suggestion so to speak; it appeals to the eye; it may weary the body; it never wearies the mind. These fairs offer an opportunity to celebrate the great idealists, who after all are the most practical men in the world. A well-arranged exposition offers to each visitor almost the ideal conditions of his early boyhood when he inquired of his father why the little hydrogen-filled balloon rose to the ceiling of the room instead of falling to the floor. It is generally conceded, I believe, that the earliest exposition on record is the one staged at Shushan by the Persian King, Ahasuerus, and described in the first chapter of the book of Esther. The Kingdom of Ahasuerus is there said to have included 127 provinces and to have extended from India to Ethiopia. The period of the exposition was 180 days and may well be called a world's fair.

It would be interesting, if time permitted, to imagine just what would have been shown at a world fair, say in Egypt 1500 B. C., or at Athens in the fifth century B. C., or at Rome about the beginning of the Christian era. One would doubtless be surprised at the new devices presented in the way of tools, boats, looms, sleight-of-hand performances, works of art, musical instruments, implements of war, pharmaceuticals; but one would hardly expect much save geometry in the way of that systematized knowledge which we call science.

Socrates is said to have enjoyed strolling down the streets of Athens, looking in at the shop doors, and seeing how many things he could do without; and we may be sure that the ancients were not a whit behind us in native curiosity and the spirit of inquiry.

Passing on to the fairs of medieval times, all these were essentially commercial. Many such glorified markets were held between the thirteenth and

THE ELECTRICAL BUILDINGS

*Courtesy of the Chicago Aerial Survey Co.*

AS SEEN LOOKING EAST FROM THE HALL OF SCIENCE. ARCHITECT, MR. RAYMOND HOOD.

nineteenth centuries; but it is not until 1756 that we meet a modern exposition, the one that was staged by the Society of Arts at London in 1756.

The prizes won at competitive shows of this kind enhanced the reputation and the business of the winner; but science was still in the hands of the individual and of a few academies. Products, not processes and much less theory, were the chief attractions. The great show at the Crystal Palace in London in 1851 was the first one of international character. Its main building in Hyde Park covered 20 acres. The architect, Sir Joseph Paxton, had been trained as a landscape gardener and the design was that of a glorified greenhouse. The attendance was about six million. Similar exhibitions rapidly followed in Paris, Munich, London, Rome, New York and Dublin.

### Centennial at Philadelphia

The Philadelphia Centennial in 1876 marks the beginning of a new era; transportation facilities in the United States were just reaching the stage which might be called ample. The Pullman sleeper, the railway post office and the dining car were all in their early stages. The great Corliss engine which dominated Machinery Hall typified the age of the automatic machine just then beginning. Maxwell's monumental treatise, "Electricity and Magnetism," had been off the Oxford Press for three years, but few regarded this great work, which unified the entire subject of electricity from the amber phenomenon of Thales to the modern radio set, as anything but a *tour de force* of mathematics—a bit of highbrow stuff.

It is true that the Belgian engineer Gramme, had on display at Philadelphia two or three small dynamos of his design. Professor Anthony and the late Professor Moler of Cornell had, in 1875, constructed a generator which was also shown there. Graham Bell and Elisha Gray each had exhibits which were listed in the official catalog under the head of "the electromagnetic telegraph"; but the average visitor then regarded the telephone (if, indeed, he had ever heard of it at all) as an electrical toy and nothing more. Sir William Thomson, returning to England, reported it, however, as the outstanding exhibit of the Centennial; a few months later Maxwell devoted to it his famous Rede Lecture; a few years later and "Their voice is gone out through all the earth and their words to the end of the world." But anything in the way of the fundamental and basic sciences at the Centennial was conspicuous by its absence. In consequence of the various experiments of Volta, Davy, Oersted, Faraday, and by the splendid mathematical descriptions of Neumann, Kirchhoff, Kelvin and Maxwell, the ground had been prepared for a rapid advance in electrical industry.

### Columbian Exposition

The result was seen in the Columbian Exposition in 1893, when next to beautiful architecture, electric lighting, electric power, electric welding played a leading rôle. An electrical carriage made occasional trips about the grounds: a Daimler petroleum motor did the same. Navigation of the air had not reached even the experimental stage. The Columbian Exposition housed some excellent things in pure science such as Lippmann's photographs in color, the gigantic Yerkes telescope just then nearly completed; but these were mostly static and represented apparatus and results rather than phenomena and processes. Industrial electricity commanded the field. Nevertheless, an international electrical congress was held; it was by this congress that the practical unit of

THE ELECTRICAL BUILDINGS
AS SEEN LOOKING EAST FROM THE HALL OF SCIENCE. ARCHITECT, MR. RAYMOND HOOD.
Courtesy of the Chicago Aerial Survey Co.

inductance, the henry, was defined and named. Another international convention was devoted to mathematics. These assemblies were honored by the presence of such men as Helmholtz, Silvanus P. Thompson, Rowland, Klein, Study, and others.

### Paris, 1900

Seven years later came the Paris Exposition, where science was exposed, so to speak, in several remarkably fine international congresses, covering not only the physical but also the social sciences. Most of the displays, were, however, again of apparatus and results rather than of phenomena and methods. The steamer *Turbinia* was at anchor in the Seine, while, in one of the halls, a beautiful turbine engine of Sir Charles Parsons was running so quietly that an English penny remained standing on edge on the top of the cylinder. But the outstanding features of the show were military and commercial. On the front of the German steamship building, in large gilded letters, one read the significant phrase "Unsere Zukunft liegt auf das Wasser." Equally impressive were the implements of war shown by the great factories at Creusot.

The newly discovered element, radium, was then very young; and no one present can ever forget the youthful Madame Curie presiding over certain sessions of the International Congress of Physics; unforgettable is also the experimental lecture in which her distinguished husband set forth, by actual demonstration, before an amazed audience, the striking and essential properties of the new element; but these features which I am mentioning belong rather to an international congress than to the exposition; they were favors to delegates; not privileges belonging to every visitor. In the same category belongs the already classical paper given by H. Poincaré upon "The Relations between Experimental and Mathematical Physics." Some beautiful electrical phenomena were shown by Prince Roland Bonaparte in his private laboratory; but these again were reserved for invited guests.

### St. Louis, 1904

Four years later came the Louisiana Purchase Exposition at St. Louis which, in spite of being a commercial competitive institution, assembled what is perhaps the most noteworthy gathering of scholars the world has ever seen in one place at one time. Here was an attempt to present not only the best that had been said and done, but also the most important pending problems in the 127 great fields of learning into which all knowledge had been profoundly and cleverly analyzed by the committee in charge of the congress. The entire plan was the product of the mind and imagination of three very wise men, Simon Newcomb, Albion W. Small and Hugo Münsterberg, none of whom, unfortunately, are any longer with us. Here again on the program was H. Poincaré, speaking upon mathematical physics; Oswald, the distinguished German chemist, spoke for philosophy, a subject to which all his later years were devoted; Woodrow Wilson discussed a wide historical topic. The addresses, which fill eight large octavo volumes, are all comprehensive without being superficial; in this respect they are markedly different from any eight volumes of papers read before specialist societies.

Here again at St. Louis the exhibits in science were mainly along the line of electrical engineering, transportation and other applied sciences. Pure science nowhere presented a united front; and the same might be said of various other expositions of recent times, such as those of Buffalo, Jamestown, Seattle, Antwerp and Stockholm, all of which I have

myself visited with especial attention to science, pure and applied.

### Chicago, 1933

The Century of Progress Exposition at Chicago was conceived, by a small group of clear minds, in the summer of 1928. From the very start they abandoned the idea of competitive exhibits and juries of award; instead of this they took as their principal theme the dependence of industry and commerce upon pure science. Their aim was not merely to entertain their visitors, but also to acknowledge and demonstrate our indebtedness to the quiet investigators of the century following the incorporation of the city of Chicago in 1833. Confidence in this plan was strengthened by the approval of men such as Michael Pupin and George E. Hale, who are at once productive scholars and men of affairs.

It was early seen that the demonstration of a theme such as this requires an exhibition of the fundamental sciences in such completeness and in such a shape as to be both understandable, adequate and attractive to the public. The trustees also recognized that in addition to science and industry no fair of this kind could hope to succeed, in its high purpose, without some lighter forms of entertainment which bring sunshine, laughter, rest, recreation and help to ameliorate the more drab circumstances of life. Music and art also are essential. Nor could any Anglo-Saxon Exposition hope to succeed unless healthful sports were fairly represented.

An inspiring theme—the service of science to society—having once been adopted, the next step was its execution. At this point Mr. Rufus Dawes, the president of the exposition, was courageous enough to ask Dr. George Burgess to go before the National Research Council and invite this body to appoint a committee for the express purpose of suggesting just what features and facts of science should be disclosed to the public in order to give an adequate conception of the method and achievements of modern science, pure and applied.

As most of you know, Dr. Burgess was, in his turn, wise enough and courageous enough to ask Dr. Frank B. Jewett to accept the chairmanship of a group of leading American scholars who, acting as an advisory committee, have given the exposition, in the most unselfish manner, a report of high order and rare completeness. The generosity of this committee will never, never be forgotten. It is upon the execution of this report that the Division of the Basic Sciences of the exposition is now engaged—and has been engaged for more than a year past.

To an audience of this intelligence, it is needless to say that the plans of large undertakings have generally to be modified during execution and that, in times of depression, these changes may be largely in the form of contractions.

For purposes of operation, medicine and geology are both grouped with the basic sciences, although each of them is largely an application of chemistry, physics and biology. Accordingly, the Division of the Basic Sciences includes the following seven sections—Mathematics, Astronomy, Physics, Chemistry, Biology, Geology and Medicine. The endeavor of these sections is to present a united front of the physical and natural sciences to the American public. Psychology has been associated with anthropology, as in the organization of the National Research Council, and will probably be housed in separate quarters assigned to anthropology.

The aim of our staff is to interpret to the American people the spirit of the National Research Council Committee as inspired by Dr. Burgess and Dr. Jewett.

In attempting this we are attempting to demonstrate the theme of the fair and to make plain what is meant by scientific method, which after all is the one outstanding achievement of the last three centuries. To show phenomena rather than apparatus is not easy; but that is what we are attempting; to show the processes of life rather than museum specimens is still more difficult but that is what we are attempting. An important part of our task is to make the atmosphere of science generally comprehended. For if science fails to recommend itself and its method to the explanation and the cure—the permanent cure—of such depressions as we are now in, it must for the present confess defeat. My own belief is that men of the same type as those who led the last century of progress will lead us through the coming century; so great is my faith in the value of good method.

Incidentally, it may be mentioned that the Chicago Exposition is cooperating with Messrs. Williams and Wilkins in the publication of a group of some twenty small volumes to be known as the "Century of Progress Series." Each of these books—five of which are already off the press—is written by a well known scholar and deals with an important section of modern science; the series as a whole will, it is hoped, represent, in a clear and simple manner, the front line of recent research.

In conclusion, may I remind you that the council of this association has cooperated with the trustees of the exposition in bringing to our next summer's meeting in Chicago a goodly number of foreign men of science? When, to the list of scholars included in our own membership, one adds the acceptances already received from overseas guests, he sees that the prospects for the exposition of science in 1933 are reasonably bright.

# HERBS, HERBALS, HERBALISTS

Some Sketches from the History of Medical Botany in the Old World

By Dr. HELEN BANCROFT

THE SCHOOL OF RURAL ECONOMY, UNIVERSITY OF OXFORD

In the very early days, many thousands of years ago, when man first began to live on this earth of ours, his need for food soon led him to distinguish those plants, or parts of plants, which were good to eat from those which were harmful; and, no doubt, at a very early stage, he also discovered that various plants had valuable tonic or curative properties, when he chewed them, or applied the bruised leaves and stems to his wounds.

The old British herbalist, John Parkinson, who lived between 1567 and 1650, and who was "Apothecary to James the First" and "Botanist to Charles the First," published a "Garden Book" in which he makes this statement: "God, the Creator of Heaven and Earth, at the beginning, when He created Adam, inspired him with the knowledge of all natural things (which successively descended to Noah afterwards, and to his posterity): for as he was able to give names to all the living Creatures according to their severall natures: so no doubt but hee had also the knowledge, both what Herbs and Fruits were fit, eyther for Meate or Medicine, for Use or for Delight."

While we can hardly agree with Parkinson that the first man knew all about herbal remedies from the beginning, there is no doubt that necessity would soon bring about the gradual acquiring of knowledge. Such knowledge would, of course, at first be handed on from generation to generation by word of mouth; and to this day, in India and Ceylon, amongst people of very old civilizations, as well as amongst the Zulus and other, more primitive, African tribes, though many wonderful plant remedies are known to the natives, they are guarded very jealously, and are still handed on from father to son by word of mouth only.

Compared with the whole history of man—covering, probably, a period of some 300,000 years—and of his knowledge of plant medicines, actual herbal writings, or "herb-books" are few, and of fairly recent date, though, as we shall see, some were produced by the Greeks, even before the time of Christ.

Amongst the accounts which are given of "healing by herbs," some are true, some are quite likely stories, some are very doubtful, and some are obviously pure imagination. In course of time, a great deal of superstition came to be attached to the use of herbal remedies, and so they fell into considerable disrepute amongst the more scientifically minded people. Scientists are now, however, beginning to investigate the chemical properties of herbs, and to understand why they may be valuable as medicines in certain cases; with the result that, in the last few years, herbal remedies have again come to be more widely used.

There is an old Jewish tradition, according to which herbal medicines were in use and were even committed to writing, in the time of King Solomon, about the tenth century before Christ. One of the thirty-nine books of King Solomon, it is said, concerned medicines, which were supposed to be largely herbal; for that the wise king knew much about plants is indicated in the first Book of Kings, in chapter four: "And he spake of the cedar tree which is in Lebanon, even unto the hyssop that springeth out of the wall." But if King

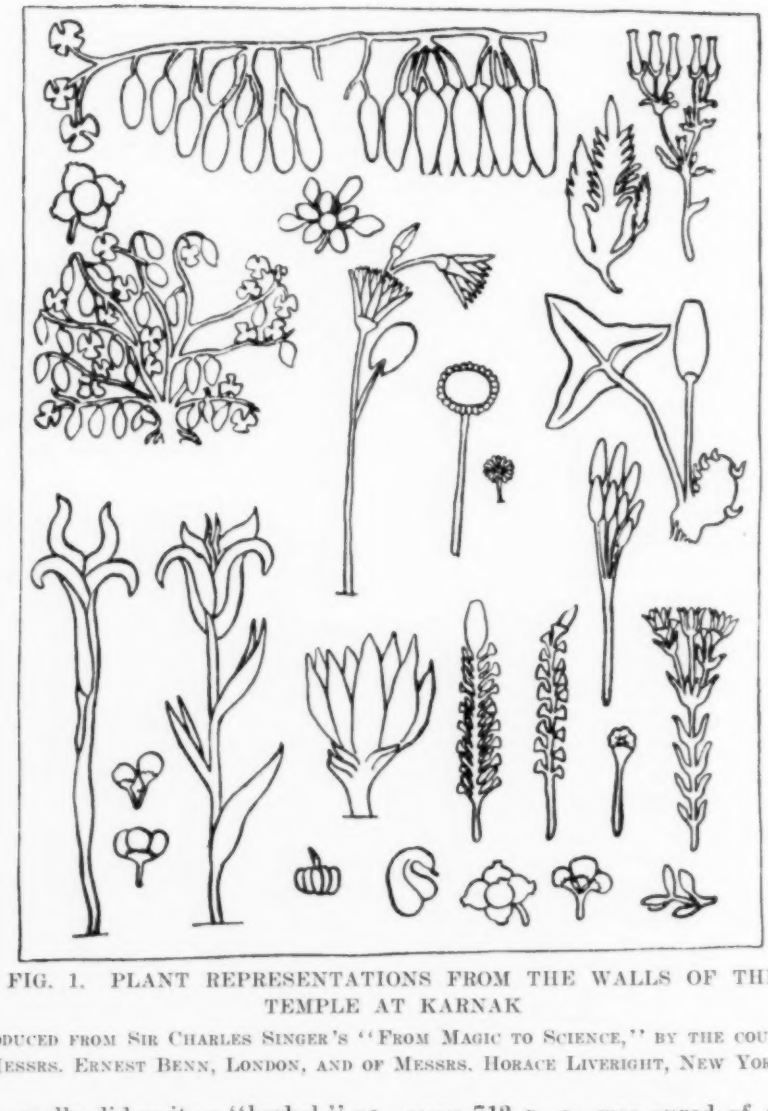


FIG. 1. PLANT REPRESENTATIONS FROM THE WALLS OF THE TEMPLE AT KARNAK

(Reproduced from Sir Charles Singer's "From Magic to Science," by the courtesy of Messrs. Ernest Benn, London, and of Messrs. Horace Liveright, New York.)

Solomon really did write a "herbal," no trace of it remains; and the Jewish tradition accounts for its loss by supposing that it was destroyed or hidden by King Hezekiah, because he thought that the people were placing too much reliance upon the use of the remedies it recommended. This is an interesting tradition, because one of the earliest definite references in literature to the use of a plant remedy is to the case of King Hezekiah himself, who, in about the year 713 B. C., was cured of a boil by placing a "lump of figs" upon it, at the bidding of the Prophet Isaiah.

But even before King Solomon reigned in Judea, there ruled in ancient Egypt a king, Thothmes the Third; and, in about 1500 B. C., this king sent an expedition to Syria, which brought back with it a number of new and strange plants. Representations of the plants were sculptured on the walls of the temple at Karnak, in Egypt, where they may be

seen to this day. The figures, which include recognizable irises and a heather, a seedling arum and a lotus flower (Fig. 1), are accompanied by an inscription, to the effect that the king caused them to be thus represented so that the knowledge of them might remain "for ever and ever." Sir Charles Singer, who is the English authority on the early herbals, calls these sculptures and their inscription a "herbal in stone"; they form the earliest *collection* of plant drawings of which we have any knowledge.

It was amongst the Greeks, however, that the study and use of plants in medical science became an established tradition, which has been handed down through the centuries. It is evident that the ancient Greeks were familiar with the use of herbal medicines at an early date; a well-known story from the Greek mythologies tells how Iapis, a favorite pupil of Apollo, was offered a choice of great skill in the foretelling of events, or in music or archery. Instead of any of these, however, he asked for a knowledge of herbs to cure disease. Armed with this knowledge, and with the help of Venus, he saved the life of Aeneas, when he was wounded by an arrow in battle. The old story says that Iapis used a purple-flowered plant called "dittany," which grew on Mount Ida in Crete (or Candia); Fig. 2 is a reproduction of a drawing of dittany from the 1636 edition of Gerard's "Herbal." Gerard describes the plant as being "hot and dry of Nature," and he adds, "it is reported likewise that the wilde Goats or Deere in Candy when they be wounded with arrows, do shake them out by eating of this plant, and heale their wounds." Dittany, it should be noted, is a relative of the marjoram which is grown in gardens as a flavoring herb, and to provide honey for bees; while herbalists to this day sometimes use this common marjoram externally for the healing of certain wounds and for easing stiff, "rheumatic-y" joints.

Returning to the ancient Greeks, we find the poet Homer, who lived during the tenth or ninth century before Christ, telling of Aesculapius, the god of healing. Aesculapius was the son of Apollo, the sun-god, and Coronis, the dawn-goddess, and he was carefully instructed by his father in the art of healing; the sun was regarded naturally, and rightly, as the restorer of life, and it was therefore natural that the sun-god's son should be endowed with curative powers. We are told that one chief source of Aesculapius' knowledge of healing was observation of the remedies resorted to by suffering animals—"what leaf or

FIG. 2. THE CRETAN HERB "DITTANY"
(REPRODUCED FROM A 1636 EDITION OF GERARD'S "HERBAL.")

berry the lizard or dormouse lay upon its wounded fellow"—and for the purpose of such observation, Aesculapius led the life of a pilgrim and wanderer in wild places for long years.

In course of time, temples were dedicated to Aesculapius, and the priests of the temples were called Aesculapiads—priest-physicians, who devoted their lives to the healing and care of sick people. Temples of Aesculapius survived in Greece and also in Italy for many years after the beginning of the Christian era. In his book, "Marius the Epicurean," Walter Pater describes such a temple near Pisa, even towards the end of the second century; at this temple, Marius saw the great physician Galen, to whom reference will be made later.

There was, then, in ancient Greece, a considerable traffic in medicinal plants, centered about these temples of Aesculapius. In course of time, however, the root-diggers and drug-sellers who made a regular business of collecting, preparing and selling these plants came to be regarded with some suspicion, because, apparently, they tried to keep their trade select by inventing superstitious stories which made it appear that herb-gathering was a very dangerous occupation. It was said, for instance, that peony fruits should be collected only at night, for if they were gathered in the daytime, and a woodpecker happened to witness the act, the eyes of the collector would be in danger. It was also said that an offering of a honey-cake must be made when *Iris fœtidissima* (the gladdon, or purple iris, sometimes found in English woods and thickets, as well as on the continent of Europe) was rooted up; and that if an eagle came near when hellebore was being gathered, the collector would die within the year. It is not surprising that people came to regard the herbalists, even in those early times, as rather ridiculous, and to feel a little suspicious of Aesculapius himself. This suspicion is expressed by the writer Lucian (about A. D. 160) in his "Dialogues of the Gods," where he makes Hercules address Aesculapius as a "wandering quack."

The ancient Greeks, therefore, believed that the gods were the first herbalists and physicians and that the art of healing was taught to man by them. The *real* founders of Greek medicine and the compilers of the Greek herbal-lore, however, were not the priests of Aesculapius, but ordinary people who wandered from place to place and earned their living by healing sick folk wherever they found them; one of the recognized and even famous herbalists of these early days was a woman named Agamēde.

The first Greek physician to work along lines more scientific and less bound up with magic and superstition than the methods of the herbalists was Hippocrates, who lived from 460 to 377 B. C. He used plants very largely as medicines—between three and four hundred are mentioned in what are known as the "Hippocratic writings"—though there is no evidence that he ever wrote an actual herbal; he probably drew upon lists of plants originally compiled by the Egyptians, for Hippocrates and other Greek physicians derived a great deal of their medical learning from Egyptian priests.

The first Greek herbal of which we have any knowledge was written about 350 B. C., by a brilliant physician called Diokles, who lived in Athens. His herbal, we are told, consisted of a description of certain plants, an account of where each might be found, and a list of its medical uses; unfortunately, this work has been lost, as well as most of the other writings of Diokles.

The next herbal of which we know is attributed to Theophrastus, a Greek philosopher who lived from about 372 to 287 B. C. Theophrastus wrote a great deal about plants, and was, as a matter of fact, the first really scientific botanist; the ninth book of his "Enquiry into

Plants" is the oldest Greek herbal which has actually come down to us. In it are described about 450 plants, knowledge of which he obtained, either at first hand on his travels, or, in the case of foreign plants, from caravan merchants. There is also a good deal of information in this herbal about the folk-lore of plants. Reference has already been made to some of the superstitious stories which the herb-gatherers invented to discourage people from entering into competition with them in their trade; the writer of this oldest-existing Greek herbal ridiculed many of these superstitions—that, for instance, which demanded the collecting of peony fruits at night only. He seemed, however, to think other superstitions quite reasonable, for he agreed that wild rose fruits and hellebore *should* be gathered "standing to windward."

After the "Theophrastan herbal," several herbal works are known to have been written in the third and second centuries B. C., but they have been partially or entirely lost; in the first century, B. C., however, a very important herbal was produced, namely that of Krateuas, physician to King Mithridates of Pontus. Krateuas not only collected herbs, but he wrote a book on their nature and uses; and later (about 75 B. C), he produced a second herbal, in which plants were not described in words, but were shown in pictures, and then discussed as to their medical uses. This illustrated herbal of Krateuas was the first of its kind, for the earlier books were without pictures of the plants described; after Krateuas, however, herbals were typically illustrated, so that Krateuas had a very far-reaching influence on the subsequent form and style of the herbal; Sir Charles Singer, in fact, calls him the "father of plant illustration."

The original drawings of Krateuas are, unfortunately, lost; but copies of them are known from a very beautiful herbal —the "Juliana Anicia" Codex—which which was written about A. D. 512 for a wedding gift to the daughter of an emperor of that time. This herbal may still be seen in what used to be the Royal Library at Vienna. One of its flower-pictures is reproduced in Fig. 3; it is evident that Krateuas was an artist of considerable merit. The plant is *Asarum europæum*,[1] the "asarabacca," which, since it was grown by monks for medicinal purposes, may occasionally be found in English woods as an "escape" from cultivation, though it is very rare; Krateuas recommended the plant for "chronic sciatica and dropsy," and also noted that it might be used in "perfumes and antidotes."

King Mithridates of Pontus, the master of Krateuas, who reigned from 111 to 64 B. C., was also an herbalist; but he was a much less reputable one than his servant, for he specialized in a knowledge of poisonous plants and used his knowledge to rid himself of people who were opposed to him. He greatly feared that

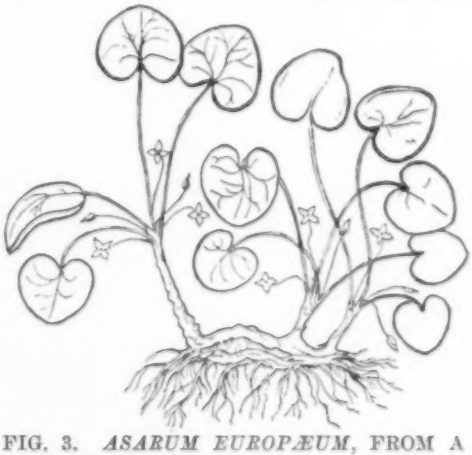


FIG. 3. *ASARUM EUROPÆUM*, FROM A SIXTH CENTURY COPY OF A DRAWING BY KRATEUAS

(Reproduced from Sir Charles Singer's "The Herbal in Antiquity," The Journal of Hellenic Studies, 1927.)

[1] A relative of the wild ginger, or Canada snakeroot (*Asarum canadense*), of N. America.

he himself would be poisoned by his enemies, so that, in order to protect himself, he prepared a complicated "antidote," which contained thirty-eight different ingredients, and which, he hoped, would give him general immunity to all poisons.

A little over a hundred years later—from A. D. 54 to 68—the herbalist Andromachus of Crete was physician to the Emperor Nero in Rome. He is especially known, because he, like King Mithridates, was a compounder of antidotes, or, as they came to be called after their royal inventor, "mithridates." The mithridate of Andromachus was even more complicated than the original, and it was to be used against every kind of poison, injury or disease. After Andromachus, the idea of the mithridate became popular, and even up to the end of the eighteenth century, it was still the custom in certain European cities to prepare, once a year, publicly and in the presence of magistrates, a "Theriaca Andromachi," an antidote which contained about 140 ingredients. The writer of this article was recently reminded of this custom when walking along a quaint old street in Moulins, a cathedral city in France, for, in a chemist's shop-window, was a large and beautiful blue-and-white earthenware jar, bearing an inscription indicating that it had contained the "Theriaca Andromachi" prepared publicly at Moulins in the year 1627. The word "theriaca" or "theriac," it may be noted, has given rise, by way of the Old French and Middle English "triacle,"[2] to the modern version "treacle," meaning "antidote," and occurring, for example, in the English common name of a wild fen-land plant, the "treacle mustard," *Erysimum Cheiranthoides*;[3] the name *Erysimum* is itself derived from two Greek words which indicate that the plant is a remedy against loss of voice.

From the time of Krateuas, many herbals have been produced by writers in Italy, Germany, England, and other European countries; and in the first century A. D., various works appeared upon which many of the later ones were based. The earliest of these first century herbals was perhaps that written by Pamphilos, a Greek physician who practiced in Rome. As, however, he apparently described plants which he had never seen, and included many supersitions in his descriptions, his work was not held in great repute.

The most famous and influential of all herbalists is Dioskurides, who became physician to the Roman army in Asia soon after the middle of the first century. Dioskurides traveled widely and was greatly interested in the plants he found, though his interest was mainly "practical," for his actual descriptions of plants were short, compared with the lists of their medical uses. His herbal was, of course, written in Greek; and in compiling it, Dioskurides undoubtedly used the works of previous writers—Hippocrates, Theophrastus, Krateuas, Pamphilos and others. Descriptions of about 500 plants were given; many of these plants were employed as drugs even in the days of Hippocrates, and are still in use—aniseed, belladonna, camomile, linseed and peppermint, for example.

[2] "Triacle," in the sense of "remedy" or "antidote," is employed by Chaucer in the "Canterbury Tales"; commenting upon the Physician's tale, the Host says:

But wel I woot, thou doost my herte to erme,
That I almost have caught a cardiacle.
By corpus bones! but I have *triacle*
Or elles a draught of moyste and corny ale,
Or but I here anon a mery tale,
Myn herte is lost for pitie of this mayde.

[3] The American common name of this plant is "worm-seed mustard." The term "treacle" is frequently applied in England to the syrupy fluid obtained in refining sugar, *i.e.*, "molasses." In conjunction with brimstone (= powdered sulphur), it forms a nursery medicine, at one time very popular. Readers of Dickens will remember that, in "Nicholas Nickelby," the boys of "Dotheboys Hall" were regularly and frequently dosed with this remedy.

FIG. 4. THE NYMPH DISCOVERY

PRESENTING A MANDRAKE TO THE PHYSICIAN DIOSKURIDES; THE MANDRAKE IS TETHERED TO A DOG AS DESCRIBED IN THE TEXT. (REPRODUCED FROM SIR CHARLES SINGER'S "FROM MAGIC TO SCIENCE," BY THE COURTESY OF MESSRS. ERNEST BENN, LONDON, AND OF MESSRS. HORACE LIVERIGHT, NEW YORK.)

Fig. 4 shows the famous herbalist receiving a mandrake from the nymph "Discovery." The mandrake is a plant around which some very curious superstitions arose, so that it became one of the most frequently illustrated plants of the herbals. There was, in the early days, a very general idea that the mandrake had human limbs, because the forking of the root sometimes suggested a likeness to the human body; this idea is plainly illustrated in Fig. 4, and also in Fig. 5. William Turner, an English physician who lived in the sixteenth century, wrote a famous herbal in which he tells, with great scorn, how "crafty theves," in order to "mocke the poore people," cut and trimmed mandrake roots to make them look like "little puppettes"; in this way, the idea of the human form of the mandrake was spread and encouraged. According to Theophrastus, mandrake leaves mixed with meal were good for wounds, and the roots, treated with wine or vinegar, for many complaints, including sleepless-

ness. The mandrake's sleep-inducing properties are illustrated by Lucius Apuleius in his famous story, "The Golden Asse"; he tells of a boy, who, having drunk a strong draught of mandrake in wine, fell down in such a deep sleep that his schoolmaster and his mother, and the servants of the household, in ignorance of what he had drunk, thought he was dead; and he was accordingly buried.

The directions given in the old herbals for the uprooting of the mandrake are very careful and minute, because it was supposed to be a plant of such great virtue. The plant was to be "earnestly delved" around with an *ivory* staff, until its "hands and feet" were uncovered; then a hungry dog was to be tethered to the root, and a piece of meat put just out of the dog's reach, so that in straining for the meat, he necessarily jerked up the root. It was popularly believed that whoever uprooted a mandrake would die as a result, and so a dog was sacrificed for this purpose; it will be noted that the dog is tethered to Discovery's mandrake in Fig. 4, and he is also shown in Fig. 5, an illustration from an early printed herbal, produced in Rome about 1484.

It must be remembered that the mandrake of the old herbals—and of the Bible also, for it is mentioned both in Genesis and in Canticles[4]—is not the same as the plant which is sometimes called mandrake in America, and which grows wild in large quantities in the woodlands east of the Mississippi River. This plant is more commonly called "May-apple," and it is a relative of the barberry frequently cultivated in shrubberies; it is widely used in modern medicine as a stimulant for the liver and for dyspepsia; whereas the original mandrake is a member of the potato family, and is not now used medicinally.

[4] Genesis, xxx, 14; Canticles, vii, 13: inferences as to the aphrodisiac properties of the herb, a belief in which is still held in the East.

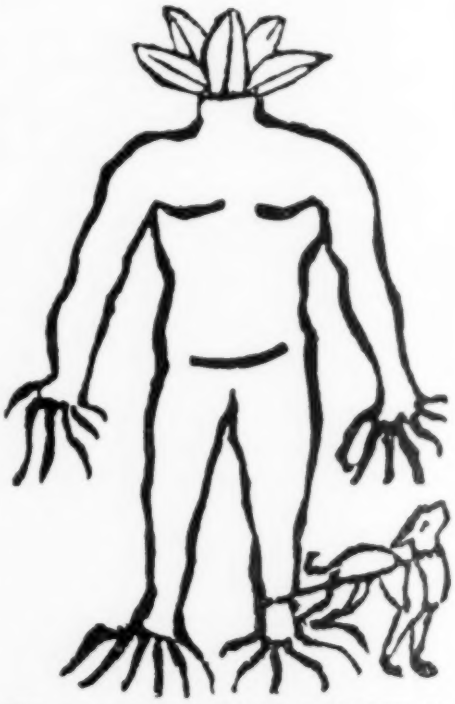


FIG. 5. A TRADITIONAL REPRESENTATION OF THE MANDRAKE

From an early Italian printed herbal (about A. D. 1484). (Reproduced from Sir Charles Singer's "From Magic to Science," by the courtesy of Messrs. Ernest Benn, London, and of Messrs. Horace Liveright, New York.)

The Dioskuridean herbal has been the main source from which later works of the same kind have been derived. Many versions were written in Greek—the "Juliana Anicia" manuscript, containing copies of the drawings of Krateuas, is one of the most famous of these. In the sixth century, Latin versions appeared; and one of these, in about A. D. 1000, gave rise (combined with another herbal to which reference will be made later) to an Anglo-Saxon herbal. The work of Dioskurides thus became widely known in Europe; and it also, through translations into Arabic, Syriac, Persian and Hebrew, came to be used in Oriental countries as well.

It has already been noted that "Marius the Epicurean" saw the physician Galen at the temple of Aesculapius, near Pisa; it is now necessary to discover something of this great man and his work. Galen was born in A. D. 130 at Pergamum in Asia Minor; he studied at the medical school in his native city, and later at Alexandria. When he was twenty-eight, he had a serious illness, caused, apparently, by eating too much fruit; he himself tells us that he owed his recovery to the god Aesculapius, whose grateful servant he henceforth became—that, of course, explains why Marius saw him at an Aesculapian temple. In A. D. 161, Galen went to Rome, where he soon made a name for himself and developed so large a private practice that other physicians were jealous of him, and he had to leave Rome for a while; when he returned, he settled down to the writing of books on many subjects —he is said to have been the author of nearly 400 works. One of these was an herbal so systematic and complete that for many years no entirely new herbal appeared; indeed, with Galen, Greek medical science may be said to have come to an end.

Galen's Greek herbal, like that of Dioskurides, was translated into Latin. Besides these "derived" Latin herbals, there were one or two "native" works, of which that of Pliny is the best known. Pliny was a contemporary of Dioskurides, and about A. D. 60, he produced an extensive Latin work on natural history, including a lengthy account of "Remedies derived from the Garden Plants." Pliny apparently collected, from all sorts of sources, ideas on the nature, origin and uses of plants. So industriously did he work at his collecting and compiling from other people's books that he considered even taking a walk to be waste of time; but his writings were so uncritical and unscientific that they were of no real value. They were, however, widely read, copied and translated for centuries, with the result that a large part of them has gradually passed into folk-lore, and the gipsy fortune-teller of to-day, as Sir Charles Singer notes, is still reciting charms and spells that Pliny himself borrowed from the works of the old Greeks, written centuries before his time.

The most important Latin herbal is that of Apuleius. It is not known who Apuleius was; he was certainly not the Lucius Apuleius who wrote "The Golden Asse," for that author lived about the same time as Galen, in the second century A. D., and the Apuleian herbal did not appear until the fourth century. The original has been lost, but numbers of later versions—which are illustrated—are still in existence. Associated with a Latin version of the Dioskuridean herbal, the Apuleian herbal was first translated into Anglo-Saxon about A. D. 1000, and later about 1120. This later translation was written at the Abbey of Bury St. Edmunds by one of the monks; and it is of great interest, because some of its flower pictures are very natural and of considerable beauty, and were evidently painted by a lover of plants. This Bury St. Edmunds herbal is still in existence, and may be seen in the Bodleian Library, at Oxford.

Versions of the Apuleian herbal were copied and recopied continually; and, when printing was invented, this herbal was one of the first books to be produced in print. Its original illustrations were also reproduced, as wood or metal "cuts." As will be seen from Figs. 5 and 6, they were rather crude; but generally they showed the plant as a whole, including its roots, which was, of course, natural in an herbal, for from the herbalist's point of view it was often the root of a plant which had special "virtues." Another feature of these illustrations is that representations of the animal whose bites or stings were supposed to be cured by the use of a particular plant, were often included with the drawing of the

FIG. 6. A REPRESENTATION OF PLANTAIN

THE WHOLE PLANT, WITH A SNAKE AND SCORPION. FROM AN EARLY ITALIAN PRINTED HERBAL (ABOUT A. D. 1484). (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

plant itself; Fig. 6, for example, shows the plantain, accompanied by a snake and a scorpion, against the attacks of which it was supposed to be an antidote.

After the invention of printing, many herbals appeared; some were based directly on the old manuscripts, others were translations of manuscripts into French or German, and some, in various languages, were more or less original. The result was that the printed herbal became wide-spread in Europe—in Germany, France, Italy, the Netherlands, Switzerland and England.

The first printed English herbal was that published in 1525 by "Rycharde Banckes" of London. We do not know who was the real author of this very charming little book; but, whoever he was, he was evidently more poetically than scientifically inclined, as his remarks concerning the herb rosemary indicate. Amongst the many "virtues" of rosemary we find the following:

"Take the flowers thereof and make a powder thereof and binde it to thy right arme in a linnen cloath and it shale make theee light and merrie."

"Boyle the leaves in white wine and washe thy face therewith and thy browes and thou shalt have a faire face."

"Also put the leaves under thy bedde and thou shalt be delivered of all evill dreames."

"Make thee a box of the wood of rosemary and smell to it and it shall preserve thy youth."

The writer of Banckes's herbal evidently drew his information about rosemary from an old manuscript which was sent to Queen Philippa of England (the wife of Edward the Third) by her mother, the Countess of Hainault. This fourteenth century manuscript records an old tradition (not, however, mentioned by Banckes) which is still held by many country people in England today, namely that rosemary "passeth not commonly in highte the highte of Christe whill He was man on Erthe." It is said that the Countess of Hainault not only sent the manuscript to her daughter, but that she sent the first plants of rosemary to England, too. This herb apparently became very costly in the reign of Charles the Second, when it was used, on account of its sweet smell, to ward off infection of the plague, which raged in London in 1665.

Banckes's herbal soon became very popular, and during the next thirty years it was reprinted many times, by different publishers, under different titles.

In 1526, there appeared what is perhaps the most famous of the early

printed herbals, namely, "The Grete Herball." This was a translation of a French printed herbal, which was itself most probably derived from a Latin manuscript.

"The Grete Herball" contains a good deal of information which is not strictly herbal; for example, it is pointed out (on the authority of Galen) that bathing is unwise, for "many folke that hath bathed them in colde wa(ter) have dyed or they came home." But this work at least marks a great advance on the methods of the old Greek herbalists and root-diggers, who, it will be remembered, hedged their trade around with secrecy and superstition; for "The Grete Herball" exposes the often-practiced frauds of the herb-sellers—the mandrake superstition, for instance, is firmly rejected.

Some of the names given to British plants in this herbal are both picturesque and interesting: the common arum is called "prestes hode"; duckweed, "lentylles of the water"; and wood-sorrel, "alleluya." The last two names are of interest, because, as we have seen, "The Grete Herball" was a translation of a French herbal; and duckweed and wood-sorrel are commonly called "lentilles d'eau" and "alleluia," respectively, in France to this day." "Alleluia" is so named because it flowers about Eastertime, when the "Alleluia" reappears in the church services, after the long Lenten season, during which it is not used.

There were various reprints of "The Grete Herball," but the next new British herbal proper was written by William Turner, between 1551 and 1568. Turner was a clergyman of the "reformed" faith, but he was continually getting into trouble with both parties in the church, and periodically he had to leave England in consequence. He traveled a good deal in Europe, and took a medical degree in Italy, where he also studied botany. He wrote several smaller botanical works before his herbal; it was in the latter that he treated the mandrake story with scorn, as already mentioned.

Then in 1597 appeared John Gerard's "Herball or Generall Historie of Plantes," a book which has made Gerard's name famous, though he does not in the least deserve his reputation, for he merely adopted and completed another writer's unfinished translation of a continental herbal. "Gerard's Herbal" is illustrated by a large number of pictures, most of them borrowed; but one of his own original illustrations is the first published representation of the potato plant. One of the borrowed pictures is an absurd and amusing one of the "Goose Tree," or "Barnakle Tree," which is reproduced in Fig. 7. Gerard was certainly not a reliable observer, for he declared that he had actually seen a goose tree on a "Small Ilande in Lancashire." His description of it is very circumstantial; he says that branches of old and rotten trees and broken pieces of ships produced whitish shells, inside each of which, in course of time, a bird was formed. When the birds were perfectly shaped, the shells opened and the birds fell out into the sea. The myth of the "Barnakle Tree" was apparently wide-spread, and was believed at least as long ago as the twelfth century; the "barnacle geese," indeed, caused the church authorities considerable difficulty, because there was doubt whether they were fish, or flesh, or neither, and whether they might, or might not, be eaten during Lent.

Gerard had a herb-garden containing 1,000 different herbs, in what is now Fetter Lane, in London. He was undoubtedly a lover of his garden flowers, and of wild flowers also, for one of the most interesting features of his herbal is his account of the plants which he found in the lanes and fields and hedges of "Piccadilla," and other places now overrun by the busy city of London.

John Parkinson, who believed that Adam was inspired with a knowledge of

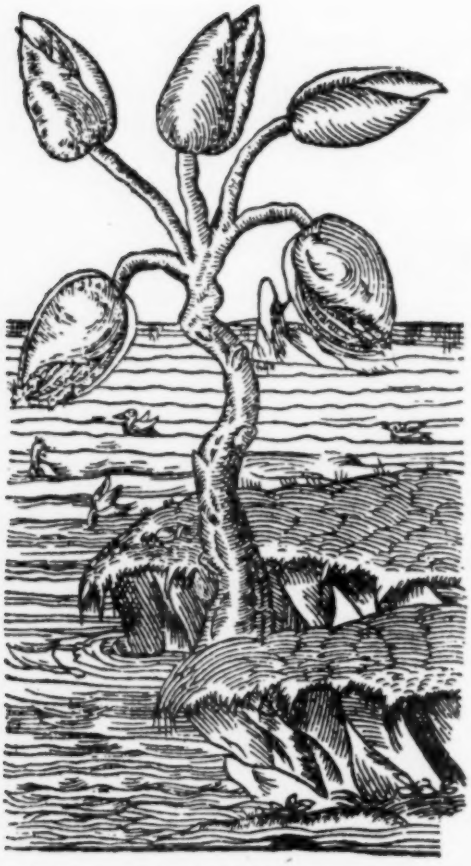


FIG. 7. THE "GOOSE TREE" OR "BARNAKLE TREE"

AS FIGURED BY GERARD, IN THE "HERBALL" OF 1597. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

the uses of all herbs, was the next British herbalist after Gerard; he also had a famous herb-garden in what is now a very busy area in London.

Some of the superstitions which became attached to various herbs have already been mentioned. We must now examine some very absurd ideas about plants which were held even as late as the sixteenth and seventeenth centuries, and which were very popular—one writer, indeed, defended them on the ground that they were "pleasant," even if untrue. These ideas may be considered under two headings—"astrological botany" and "the doctrine of signatures."

### ASTROLOGICAL BOTANY

In Babylon, as long ago as 3,000 years before the birth of Christ, men came to believe that they, and all other animals, and all plants and minerals were under the influence of the planets. Each plant was held to be governed by some particular star, which caused the seedling to push out of the ground when the seed germinated. A belief in the influence of the moon upon plants is shown in Pliny's "Natural History" (written about A. D. 60), where we read that the Druids in Britain gathered the mistletoe for medical purposes when the moon was six days old. In most cases it is impossible to discover why an herb was associated with one planet rather than with another; but in some cases, the shapes of the leaves or fruits suggested an association—with the moon, for example, as in the case of the fern "moonwort," shown at the right-hand side of Fig. 8. In the seventeenth century a belief in astrological botany was very wide-spread in England, the great advocate of the subject being Nicholas Culpeper, who lived between 1616 and 1654. Culpeper was a "physician-astrologer," not at all popular with the more orthodox members of the medical profession—which is not surprising, for he called them "a company of proud, insulting, domineering Doctors"; he also claimed that his methods were far superior to those of previous astrological herbalists, being guided by reason, whereas their writings were "as full of nonsense and contradiction as an Egg is ful of meat." He wrote a book called the "Physicall Directory," which was reprinted many times; the 1653 edition was described as a discourse showing how "a man may preserve his Body in Health; or Cure

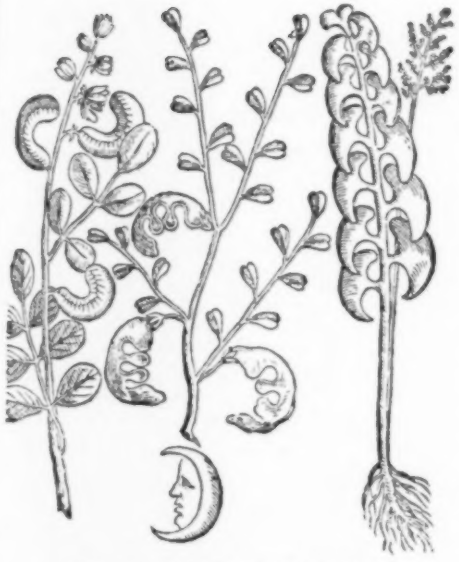


FIG. 8. "LUNAR HERBS"
AS FIGURED BY GIAMBATTISTA DELLA PORTA IN 1591. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

himself, being Sick, for three pence Charge, with such things only as grow in England, they being most fit for English Bodies." In "Rewards and Fairies," Mr. Rudyard Kipling tells a story entitled "A Doctor of Medicine," which gives a delightful idea of the "very simple soul" combined with "a high courage tempered with sound and stubborn conceit" which Culpeper must have been. He met with much criticism, particularly from one William Cole, who wrote very scathingly of him soon after his death. Cole's arguments against astrological botany were very ingenious; he contended that since plants were created on the third day, and the sun, moon and stars on the fourth day, there can be no dependence of plants upon the planets: for "Plants were, even when Planets were not."

### THE DOCTRINE OF SIGNATURES

This was a mystical idea which was, to a certain extent, combined with astrological botany; according to it, plants were "signed," so to speak, by their form and color and scent, in such a way as to indicate what are their healing properties; Fig. 9 shows plants, the form of whose fruits or flowering spikes suggests that they are remedies for scorpion stings.

A belief in signatures was indicated in the old botanical writings long before it was definitely stated by Paracelsus, a German alchemist, born in 1493. Paracelsus was the son of a doctor, and he himself became a professor of medicine at Basle, where he publicly burnt the works of Galen and other physicians. He had considerable influence on the study of medicine, for he was an able chemist, and pointed out the need for applying chemistry to medicine. Paracelsus was extremely boastful and violent-tempered, and consequently found it impossible to remain long in any one place; he wandered about from country to country, now prosperous and famous, now poor and disgraced. Robert Browning's poem "Paracelsus" gives a vivid idea of his strange career.

The doctrine of signatures was developed by a Neapolitan scientist and writer named Giambattista Della Porta, in 1588. Porta not only believed that plants were "signed" by their form and growth, color and scent; he also held that plants with short or long lives could be used to shorten or lengthen human lives, and that the plants of a particular area were intended to cure the diseases of the people living there. This last idea is interesting, because it led to the discovery of "salicin," used in the treatment of rheumatic fever; this substance occurs in the bark of the willow, which of course grows by water or in damp places likely to induce rheumatism.

The great English advocate for the doctrine of signatures was William Cole, who, however, as we have already seen, ridiculed the idea of "astrological botany." William Cole was born in 1626, at Adderbury near Oxford; he died

FIG. 9. "HERBS OF THE SCORPION"

AS FIGURED BY GIAMBATTISTA DELLA PORTA IN 1591. (REPRODUCED FROM MRS. ARBER'S "HERBALS," BY THE COURTESY OF THE CAMBRIDGE UNIVERSITY PRESS.)

when he was only thirty-six, a few years after writing a rather famous book, "Adam in Eden." In this work, he shows how the "wall-nut" has the "perfect Signature of the Head"; the kernel, for example, "hath the very figure of the Brain, and therefore it is very profitable for the Brain, and resists poysons; For if the Kernel be bruised, and moystened with the quintessence of Wine, and laid upon the Crown of the Head, it comforts the brain and head mightily."

Cole was much puzzled by the fact that many herbs with undoubted medicinal virtues were left "unsigned"; he concluded that some were signed in order to put man in the right way in his search for remedies, and that others were left without signatures to encourage him to research and find out their properties for himself.

Another supporter of the doctrine of signatures in England was Robert Turner, the writer of "The Brittish Physician" (1664), in which is mentioned the

Jewish tradition concerning the herbals of King Solomon. Robert Turner, unlike William Cole, was a firm believer in astrological botany.

### Conclusion

As Mr. Kipling says, in "Rewards and Fairies,"

> Anything green that grew out of the mould
> Was an excellent herb to our fathers of old.

But—

> Half their remedies cured you dead—
> Most of their teaching was quite untrue—

and there is little wonder that under the influence of mystical ideas like astrological botany and the doctrine of signatures, herbal remedies and the trade of the wandering herbalists, or "green men," as they were called, fell into disrepute.[5]

General public interest in medicinal herbs has, however, been revived within the present century as a result of several factors, one of which was the great war of 1914–18. The growing of drug-yielding herbs, at the outbreak of the war, was largely in the hands of Germany and Austria; and in order to keep up supplies of various drugs, in England more particularly, it was necessary that the plants providing them should be, as far as possible, cultivated and prepared in the country. Various associations for these purposes were therefore formed, and, in England at least, a useful, and, it is to be hoped, a lasting interest in this medical aspect of wild and garden plants was thus encouraged.

[5] It may interest American visitors to England to be reminded that the itinerant herbalists gave their name to various inns up and down the country. "The Green Man" at Ashbourne, near the famous Dove Dale, is a notable example.

Another factor which perhaps stimulated a good deal of interest in medicinal herbs, more particularly in America, was the appearance of Mrs. Gene Stratton Porter's novel "The Harvester." The Harvester, it will be remembered, was an American herb-cultivator, one of his "crops" being ginseng, the root of which has tonic properties; it has much the same shape as a mandrake root, and indeed there is a Chinese legend of the ginseng plant very similar to the early European story of the mandrake.

The foregoing sketches from the "History of Medical Botany" will indicate how this utilitarian aspect of an interest in plants has passed through the various stages of observation, tradition, guesswork and superstition, and finally emerged as a scientific study. A knowledge of chemistry, as Paracelsus even in his day realized, is essential to the treatment of disease; and exact chemical research has now revealed the valuable curative properties of many herbs and plants, as in the case of the drug "salicin," already mentioned, and also in that, for example, of the volatile oil obtained from the wild carrot and found to be of use in the treatment of asthma. This is an interesting case, for the celebrated John Wesley, in a small treatise entitled "Primitive Physic, or an Easy and Natural Method for Curing Most Diseases" (1769), advised sufferers from asthma to "live a fortnight on boiled Carrots only."

Herbal treatment is, in fact, no longer an empirical matter; being founded, as it now is, on scientific research and observation, there is every likelihood that herbs will be increasingly utilized once more as healers of the physical ills of mankind.

# EINSTEIN'S THEORY AND RATIONAL LANGUAGE[1]

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## Introductory Remark

It is a fact that even highly educated laymen have very little understanding of the relativity theory. What largely contributes to this is that in expounding the theory phrases are used to which attaches a mystical meaning, or which convey no meaning at all, in ordinary language. These phrases are the expressions "fourth dimension" and "curved space." It is difficult to do without them in an interpretation of the theory. Yet this is not only feasible but even renders it better intelligible. The term "four dimensions" seems to be unavoidable in describing Minkowski's "World" which plays a most important part in the relativity theory. The following characterization of this author's idea, however, shows that his "world," which remains an enigma to the layman by reason of that confusing expression, becomes understandable to him when its description keeps clear of it. The same holds true of the bewildering term "space curvature" in explaining the rôle of the Euclidean geometry in the general relativity theory.

## Minkowski's World in the Relativity Theory

An aggregate of elements of the same kind is a continuum if their sequence is uninterrupted, if one element is contiguous to another or others. A line is a continuum whose elements are points. A point in a line touches two other points. A surface and the space, too, are continua with points as elements. A point in a surface, however, adjoins an infinite number of other points, and in space a still greater infinity of other points. There are other differences between these three continua. The most important one relates to the location of a point.

Mathematicians and physicists are very often confronted with the necessity of locating a point in one of the three continua. A point in a line is determined by its distance, $x_1$, from another point in it fixed arbitrarily. No other measurement is needed than that of this distance to find the point sought. A line is therefore a continuum of one variable, $x_1$. To obtain a point in a surface, two straight lines in it intersecting each other —it is convenient but not necessary to make the angle of intersection a right one—are selected arbitrarily. Any point in the surface is then given when its distances, $x_1$ and $x_2$, from the two lines are known. Two measurements are needed in this case. A surface is therefore a continuum of two variables, $x_1$ and $x_2$. To locate a point in the space, finally, we fix arbitrarily three straight lines in it which intersect each other in one point, usually—but not necessarily—at right angles. Any point in the space can be found through its distances, $x_1$, $x_2$, $x_3$, from the three lines. The space is a continuum of three variables, $x_1$, $x_2$, $x_3$.

Time is an aggregate of equal elements, of instants. There is no break between them; one instant is always preceded by another and followed by still another. Time is therefore a continuum. If one instant in it is fixed arbitrarily, any other instant is determined through the interval, t, between it and the fixed

[1] Rationality and greatest possible expressiveness characterize the Model Language, the idea of which was broached by the writer in Scientific Monthly, April, 1929.

instant. This interval is measurable and nothing else needs to be measured to find the instant sought. Time is therefore a continuum of one variable, t.

In the prerelativistic era space and time appear disconnected, independent of one another. This is expressed in the Galilei-transformations: $x' = x - vt$; $t' = t$. We see from these equations that in going over from one system, K, into another, K', which is in motion relative to K, a spatial distance changes, but a time interval remains the same. The special relativity theory has divested time of this independence. The equation, $t' = (t - xv/c^2)/q$, which is one of the Lorentz-transformations figuring in the relativity theory and wherein $q = \sqrt{(1 - v^2/c^2)}$, indicates that a change of the spatial distance x of the system K conditions a change of the time interval t' in the system K'. Time stands in relation to space.

This principle of interdependence of space and time is clearly embodied in Minkowski's "World." It is represented by the totality of the physical events in the universe, and time and space are not separate continua in it, but closely knit together, forming an indissoluble unity, the space-time continuum. That space and time do not exist each by itself, alone, is obvious. A certain point is always found at some instant, and a certain instant is always noticed at some point. An event always occurs both in some point and at some instant. This means that space and time are not severable and one always coexists with the other. The mathematician Hermann Minkowski was the first to emphasize this inseparableness of space and time. In a lecture before the Physicists and Physicians at Cologne on September 21, 1908, he prophetically expressed in the following words the idea that space and time will be treated in physics always as coexistent: "From this hour on shall space by itself and time by itself completely sink down to shadows, and only a sort of union of both shall preserve independence."[2]

Space and time, accordingly, are to be considered jointly in describing the physical events. Indeed, an event always comprises both a spatial point and an instant. It is determined only when both are given. The united space-time is composed of equal elements, of events, and forms a continuum since every event is contiguous to other events. The space-time continuum has four variables. Minkowski calls an event a "world-point." It is determined through three spatial variables and one time variable. A series of consecutive world-points constitutes a "world-line."

The chief advantage accruing for the relativity theory from Minkowski's union of space and time is that in developing this conception he devised a method of making the time variable play formally in mathematical calculations exactly the same part as any one of the space variables. He showed that if to the time variable is given the value $tc\sqrt{-1}$ instead of t, and $x_4 = tc\sqrt{-1}$, then $x_4$ enters into all calculations in the same way as a space variable. The four variables of the space-time continuum are then simply $x_1$, $x_2$, $x_3$, $x_4$, and the last one relating to time does not differ from the other three as far as algebraic operations are concerned. This makes it possible to apply in calculations referring to the space-time continuum of four variables the same Euclidean geometrical methods as are used for the space continuum of three variables. A distance between two points in the latter, for instance, is given through the equation $d^2 = x_1^2 + x_2^2 + x_3^2$. In the same way the distance between two world-points is expressed through the analogous equation $d^2 = x_1^2 + x_2^2 + x_3^2 + x_4^2$. Through this device, namely, $x_4 = tc\sqrt{-1}$, the

[2] Literal translation from German; see "Model Language," No. IV, SCIENTIFIC MONTHLY, April, 1929.

mathematics of the relativity theory has been greatly simplified and clarified. Max Born even states that "without this mathematical auxiliary the general relativity theory would be unconceivable." This statement agrees, on the whole, with Einstein's remark that "without the important idea of Minkowski the general relativity theory would, perhaps, have remained in its infancy."

### Rational Language and Intelligibility of the Relativity Theory

The preceding presentation of Minkowski's "World" could have been given, as far as language is concerned, much more conveniently through the use of the term "dimension" and its derivatives. Yet they have been avoided advisedly. For the layman the expressions "four dimensions," "four-dimensional" comprise something weird, savor of mysticism and are confusing. "Dimension" does not mean the same in ordinary as in mathematical language. In the former it signifies one of the three directions of a body represented by length, breadth and thickness, that is, by three straight lines perpendicular to each other in one point. The layman therefore can not but consider a fourth dimension as something impossible. There can not be a straight line perpendicular to three other straight lines in one point in which they intersect each other at right angles. For this reason a layman has the feeling as though a cabalistic atmosphere pervaded a system in which four dimensions are figuring, as is the case with the relativity theory.

Nothing mysterious attaches to the expression "four dimensions" for the mathematician. For in geometry "dimension" signifies any direction in a body, not only one of the three represented by length, breadth, and thickness. A body has therefore an infinite number of dimensions. In algebraic operations "dimension" means simply a quantity susceptible of change, a variable. Minkowski's "World" can be made intelligible to the layman by replacing the word "dimension" with the noun "variable" in describing it, as we have seen above. Yet the mathematician can not do without the former because he needs quite frequently also the derivative "dimensional," and particularly the adjective "four-dimensional," pertaining to four dimensions. Owing to the irregularity of our languages such adjectives can not be formed from the noun "variable." For this reason a derivative of the noun "dimension" has to be used where one from the noun "variable" would suffice and be clearer for the layman. The adjective "pertaining to four variables" is too inconvenient in mathematical writings, rendering the adjective "four-dimensional" all but indispensable. If our languages permitted to construct in the same way the corresponding derivative from the noun "variable," the adjective "four-dimensional," obscure to the layman, could be avoided.

The preceding considerations furnish a striking illustration for the usefulness of a rationally constructed language, the Model Language.[3] In Arulo, the basis of the Model Language (not to be confounded with International Language which cares little for strict rationality), the two nouns discussed above are: dimensiono, dimension; varieblajo, a variable. Adjectives are formable from both in the same way: quar-dimensional, four-dimensional; quar-varieblajal, pertaining to four variables. The last adjective is the one which is needed for a smooth presentation of Minkowski's "World" but does not exist in a convenient form in the natural languages. The relativity theory can be explained to a layman in Arulo better than in a natural language and to mathematical student at least as well.

[3] Scientific Monthly, April, 1929; *Mod. Lang. Jour.*, February, 1930.

### Euclidean Geometry in the Relativity Theory

Similar considerations obtain regarding the expression "space curvature," as the following discussion shows. A straight line is indeterminable in a gravitational field. For the means of ascertaining it is a light ray and the latter is bent in such a system. Nor can a length be measured in a gravitational field because it varies in it from place to place. Euclidean geometry being based upon the conception of the straight length becomes therefore useless in describing the natural phenomena in a gravitational field. Nevertheless the validity of the Euclidean geometry is just as intact as it ever was before the general relativity theory. This can not be emphasized strongly enough because the relativistic literature, partly through vague or emotional language, has created the impression that the relativity theory has overthrown the Euclidean geometry. "The whole edifice of the Euclidean geometry is tottering," remarks Born, and "a single man, Albert Einstein, destroyed confidence in the evidence of the Euclidean geometry" according to Weyl. Such utterances by great authorities are bound to mislead the layman into believing that the relativity theory has entirely invalidated the methods of Euclid. Nothing is further from the truth than this. That geometry lost as little of its validity by being inapplicable to large parts of the space in a gravitational field as by its inapplicability on a large scale, discovered by Gauss, in surveying a tract of land of an uneven surface. According to Gauss the surveyor has to divide the surface into small parts. He then measures these by Euclidean methods and adds the results obtained, thus ascertaining the area of the whole tract. Gauss showed a way of treating such a surface geometrically without using Euclidean principles. This way led to the development of the non-Euclidean geometries of Riemann and others. Only such a geometry can be applied to extensive parts of the space in a gravitational field. This does not at all mean that Euclidean geometry is not valid.

The quality of the space in a gravitational field rendering Euclidean geometry inapplicable to extensive parts of it has been designated as "space curvature." This was an unfortunate expression. It has produced no mean confusion. It has enshrouded the relativity theory with a cabalistic veil and has furnished grist to the mill of the mystics and abettors of the modern tendency to elevate the unconscious, the vague, the unreasonable above the conscious, the clear, the rational. The meaningless confusing phrase "space is curved" can and should be avoided in treating the relativity theory. Space is not "curved" outside of a gravitational field nor inside of it. Space is only non-Euclidean here, that is, Euclidean geometry is inapplicable to it on a large scale. But minute parts of it admit very well of treatment by that method. The use of the bewildering phrase "space curvature" is due to the inadequacy of the natural languages. A noun is needed to designate the above-mentioned quality. In German one can not form from the adjective "uneuklidisch" a noun corresponding to the English substantive non-Euclideanism formable from the adjective non-Euclidean. German authors, therefore, used the expression "Raumkrümmung," space curvature, to denote that quality which, in the end, is due to a straight line being indeterminable in a gravitational field. English writers followed their example although they did not need to do this. In a rationally constructed language such perplexing words can always be avoided in expounding the relativity theory. Thereby it becomes free of all mysteriousness and can be made comprehensible to the educated layman.[4]

[4] This article, just as "The Fundamentals of the Relativity Theory" (Scientific Monthly, January, 1932), is an extract of a book to be published in the future.

# SAILORS, COCONUTS AND MONKEYS

By Dr. S. A. SCHELKUNOFF

BELL TELEPHONE LABORATORIES

At one time or another probably every reader has been puzzled by some problem which belongs to a branch of mathematics, fascinating in itself, but very little known to laymen. Thus in recent days, there has been a renewal of popular interest in the problem of the sailors, coconuts and monkeys.

It seems that five sailors, wrecked on a South Sea island and in search of food, knocked down enough coconuts to last them for months but were too tired to divide them into equal shares on the same day. That night one of the sailors woke up and decided to take his share; but on dividing the supply into five equal piles, he discovered that one coconut was left over. In order to make his problem simple, he threw the extra coconut to the monkeys and took one of the piles away. Later on, another sailor awoke and decided to take his fifth. Not knowing that the first sailor had already taken his share, he divided the supply into five equal parts, but found one coconut left over. Like the first sailor, he threw it to the monkeys and took what he thought belonged to him. As the night wore on, the remaining sailors did the same, always finding themselves in the predicament of having an extra coconut and always disposing of it in the same manner. In the morning the five sailors divided what was left into five equal piles, and this time they accomplished the division without having to throw away any coconuts. The problem is to find how many coconuts there were at the beginning.

This problem is one in Diophantine Analysis, the branch of mathematics dealing with the solution of systems of equations in which the number of unknown quantities exceeds the number of equations and the solutions are required to be in integers. The analysis is named for Diophantus, a Greek mathematician, who seems to have been the first to become interested in such problems. One of the most brilliant of mathematicians, Diophantus lived about 250 A. D., but there is definitely known about him only that he died at the age of 84, from his epitaph reading: "Diophantus passed one sixth of his life in childhood, one twelfth in youth and one seventh more as a bachelor; five years after his marriage was born a son who died four years before his father, at half his father's ultimate age."

The problem of the coconuts can be set up as an equation of the type $ax + by = c$. Of course there is no trick in solving this equation if $x$ and $y$ are unrestricted, for one can choose any value whatever for one of these unknowns, substitute it in the equation and solve for the other unknown, thus obtaining an indefinite number of solutions, one for each choice. When $x$ and $y$ are required to be integers, the solutions, though far less numerous in any particular range of values, may still be indefinite in total number. If, however, $x$ and $y$ are required to be not only integral but positive, the equation may possess only a finite number of solutions or even none at all (Fig. 1).

It can be shown that, if $x = p$ and $y = q$ constitute an integral solution of the equation, all the other integral solutions can be obtained from this by substituting all the integers successively for $t$ in the formulas $x = p + bt$ *and* $y = q - at$. Thus the problem can be reduced to

that of finding any one solution to the original equation.

Diophantus solved each equation by a method peculiar to it; in common with most of the ancient mathematicians, he was interested in obtaining a specific solution rather than in developing general methods of procedure. General methods have since been developed for handling the simpler types of Diophantine problems, including that under which the problem of the coconuts falls. There are many more types, however, for whose solution general methods are not even to-day available. It is interesting, therefore, to consider a special method of solution such as Diophantus might have used for this problem, for it illustrates in a simple way the homely modes of procedure upon which mathematicians must still rely in many more complicated kinds of Diophantine problems.

Roughly this mode of procedure may be described as paring down the equation until a solution can be obtained by inspection. The paring down is accomplished by applying the theorem that every integer, and thus each quantity in the equation, can be expressed as the product of one and only one set of prime factors. Thus if the coefficients on one side of the equation are observed to have a number $d$ as a factor, the other side must also have this factor—if not in its coefficients, then in its unknowns, since the equation asserts that both the sides are the same number. The unknown can then be replaced by $d$ times a new unknown, and $d$ can be cancelled from both sides of the equation. By successive application of this device, the coefficients of the equation in the new unknowns are made small enough to permit a solution by inspection. The values of the original unknowns can be obtained from the solution for the new by multiplying the latter by such factors as were cancelled out. The detailed solution of the problem of the coconuts by this method is shown in Example I.

There are two general methods for finding Diophantine solutions of linear equations such as $ax + by = c$. One employs continued fractions, and the other makes use of notions from the Theory of Numbers.[1] In the latter method the equation is written $ax = c \pmod{b}$, which is read "$ax$ is congruent to $c$ modulo $b$," the mathematician's way of saying that $ax - c$ is divisible by $b$ without remainder.

A Diophantine problem may offer not one but several simultaneous equations for solution. Such a problem is that of determining the numbers of those years in which Easter Day falls on a given date, which is reducible to the problem

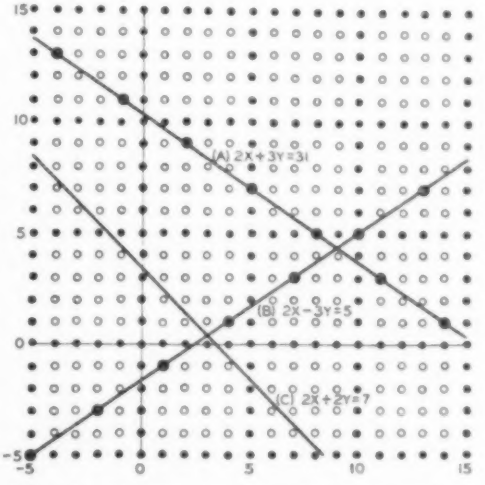


FIG. 1. FINDING THE INTEGRAL SOLUTIONS TO AN EQUATION IN TWO VARIABLES CORRESPONDS TO FINDING THE POINTS WITH INTEGRAL COORDINATES THROUGH WHICH THE GRAPH OF THE EQUATION PASSES. IN THE ABOVE GRAPHS OF THREE LINEAR EQUATIONS, IT CAN BE OBSERVED THAT ONE (A) HAS ONLY A FINITE NUMBER OF SOLUTIONS IN POSITIVE INTEGERS, ANOTHER (B) AN INFINITE NUMBER, AND THE THIRD (C) NO INTEGRAL SOLUTIONS EITHER NEGATIVE OR POSITIVE.

[1] For the former consult G. Chrystal's "Algebra," Vol. II, page 473; and for the latter any elementary treatise on the Theory of Numbers, under the heading "Linear Congruences."

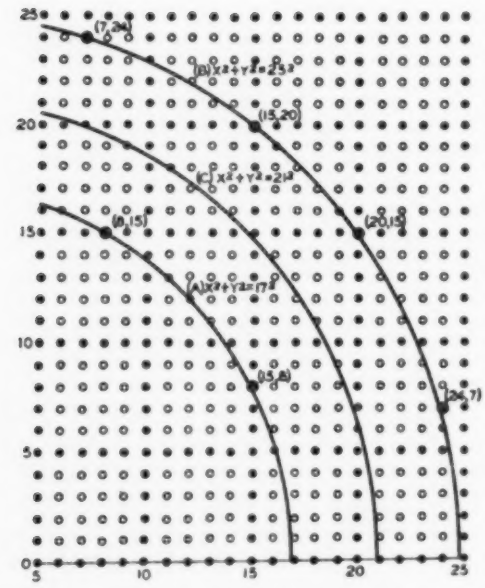


FIG. 2. THERE MAY BE (A) ONE PAIR OF INTEGERS, (B) SEVERAL PAIRS OF INTEGERS, OR (C) NO PAIRS OF INTEGERS, THE SUM OF WHOSE SQUARES IS A GIVEN SQUARE.

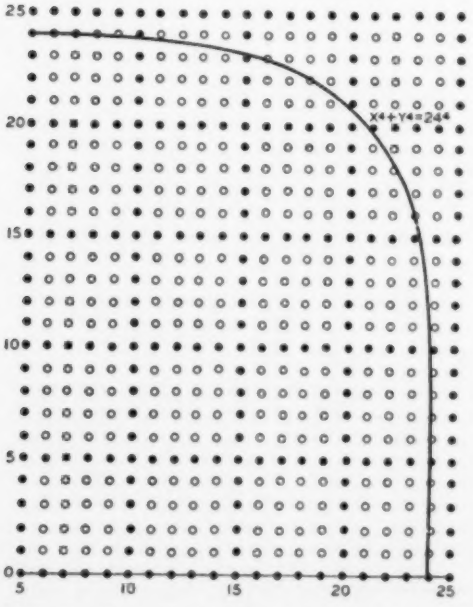


FIG. 3. IT IS STRANGE BUT TRUE THAT THE ENTIRE FAMILY OF CURVES OF THE TYPE $x^4 + y^4 = z^4$, OF WHICH ONE MEMBER IS SHOWN ABOVE, PASS THUOUGH NO POINTS WITH INTEGRAL COORDINATES.

of solving the six equations with eleven unknowns shown as Example II. Diophantine equations may also be quadratic or of even higher degree. Thus one may wish to find two integers, the sum of whose squares is the square of another integer (Fig. 2). Some solutions can be easily guessed, and all the solutions can be obtained with the aid of certain formulae, as shown in Example III. For the solution of equations of higher degree than the second, no general methods have yet been discovered.

Perhaps the most famous problem in Diophantine Analysis is that known as "Fermat's Last Theorem," after the French mathematician who first stated it, without proof, to the effect that the equation $x^n + y^n = z^n$ can not be solved in integers if $n$ is greater than 2 (Fig. 3). Euler proved the theorem for $n = 3$ and $n = 4$; Dirichlet for $n = 5$ and $n = 6$; G. Lamé for $n = 7$; and Kummer for many other values. The problem has never been solved with complete generality, although numerous and handsome prizes have been offered by various scientific societies for the complete solution, and new branches of mathematics have been discovered in the course of attempts to provide such a solution.

**Example I—The problem of the sailors, monkeys and coconuts can be resolved into that of finding the integral solutions of a linear equation in two unknowns.**

EXAMPLE I

**Let x equal the original number of coconuts.**
**The first sailor took 1/5 (x − 1) coconuts and left 4/5 (x − 1).**
**The second took 1/5 [4/5 (x − 1) − 1] and left 4/5 [4/5 (x − 1) − 1].**
**The fifth sailor thus left $(\frac{4}{5})^5(x-1) - (\frac{4}{5})^4 - (\frac{4}{5})^3 - (\frac{4}{5})^2 - \frac{4}{5}$.**
**Since this amount was divisible by 5, it can be called 5y.**
**Thus: $(\frac{4}{5})^5 (x-1) - (\frac{4}{5})^4 - (\frac{4}{5})^3 - (\frac{4}{5})^2 - \frac{4}{5} = 5y$.**
**Adding terms and clearing of fractions:**
**$4^5x - 4 \cdot 5^3 + 4^3 = 5^5y$.**
**Since y must be divisible by 4, let $y = 4v$.**

Then: $4^4x - 5^3 + 4^5 = 5^4v$;
Or: $4^4 (x+4) = 5^3 (1+5v)$.
Since $x+4$ must be divisible by $5^3$, let $x+4 = 5^3w$.
Then: $5v+1 = 4^4 w$; or: $5v+1 = 256\,w$.
An obvious solution of this equation is $w=1$, $v=51$.
Then all solutions for w and v can be found from:
$w = 1+5t$, $v = 51+256t$.
Hence the formulae for x and y are:
$x = 3121 + 15625t$, $y = 204 + 1024t$, where t is zero or any positive integer.

Thus the smallest number of coconuts there could have been is 3,121, of which each sailor would receive 204 the following morning.

Example II—The problem of finding the years in which Easter Day falls on a given date is that of finding the integral values of N which simultaneously satisfy six linear equations in eleven unknowns.

EXAMPLE II

Let N be the number of the year; and let w be the date of Easter Day in March or w–31 be the date in April.

Then: $N = 19x + a$
$N = 4y + b$
$N = 7z + c$
$19a + 15 = 30u + d$
$2b + 4c + 6d + 6 = 7v + e$
$w = d + e + 22$
where: $a < 19$, $b < 4$, $c < 7$, $d < 30$, $e < 7$.

Example III—The problem of finding three integers such that the sum of the squares of two of them equals the square of the third furnishes a quadratic Diophantine equation.

EXAMPLE III

Consider the equation $x^2 + y^2 = z^2$.
Some integral solutions can be easily guessed:
$x = 3$, $y = 4$, $z = 5$.
$x = 5$, $y = 12$, $z = 13$.

All integral solutions can be found from the following formulae, by allowing m and n to take successively all integral values such that m is greater than n:

$x = m^2 - n^2$, $y = 2\,mn$, $z = m^2 + n^2$.

It is readily seen that the equation is satisfied identically when these formulae are substituted in it.

# SEWAGE DISPOSAL DEVELOPMENT IN THE UNITED STATES

By GEORGE L. ROBINSON
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It was not until after the Spanish War, with its dreadful typhoid record, that the problem of the sanitary disposal of sewage was actively taken up by the American engineers, chemists and bacteriologists.

To be sure, with the development of sewer systems in our cities, towns and institutions, some attempt had been made to separate the organic matter from the waste water, but it was done with the thought of preventing unpleasant odors and unsightliness rather than a health protection.

The Massachusetts State Board of Health conducted a series of most valuable experiments at Lawrence and gave out its report as early as 1890. This report was about the first original data from an American source which had real value. These studies were directed along lines of sand filter experiments together with screens rather than any special plan of tank action on the sewage. It was quite natural that under favorable conditions the sand filter beds should be used, as with cheap land and labor and under proper rotation they did produce an effluent of a high degree of purity. However when it became so evident that flies and other insects carried infection from unclean organic matter to food supply and that the intestinal germs infected water supply then the engineers became interested in planning means of purifying the sewage before or during the process of disposal.

It had of course long been known that the oxygen content of the average stream was enough to reduce the or-

ganic matter in sewage so it would not become offensive and would in fact under favorable conditions produce complete ultimate purification. This dilution method has been followed in nearly every city and town in the country. If the streams were large enough and there were no down stream water supplies to be involved the plan did work satisfactorily for many years. It is said that there must be a stream flow of more than three cubic feet per second to dilute and oxidize the sewage production from an average group of one thousand persons. Of course as soon as trade waste, dyes and other chemical by-products reach the sewers the dilution plan fails at once. This is one of the chief causes of stream pollution and the chemicals result in the impairment of the river water to such an extent that the domestic sewage will not break down and properly oxidize.

About the year 1900 the so-called septic tank began to demand the attention of our engineers as a method of breaking down organic matter in sewage by means of the natural fermentation setup due to the action of anaerobic bacteria. The first claims for the septic tank as a purifying agent were very grossly exaggerated and led to much misunderstanding among the uninformed. This has unfortunately continued to this day.

Among the first experiences with septic tanks on a large scale was the Saratoga Springs Cameron Septic Tank installation which resulted in claims of patent rights and long legal investigation as to their validity. These were heard in the federal courts and while some counts were held in favor of the Cameron Company it finally resulted in an understanding of the subject so that engineers could make up designs of tanks without fear of royalty claims.

The Cameron tank is what is generally understood as a one story settling or septic tank, large enough to hold a day's flow in a state of quiescence, thereby enabling anaerobic bacterial fermentation to develop. The process does liquefy and gasify organic matter to a considerable degree and does produce in time a non-putrescible sludge which forms at the bottom of the tank. The effluent, however, though frequently quite clear, is laden with organic matter in solution and suspension and will quickly become malodorous. It is necessary to provide a secondary treatment either by sand filtration or by spraying over broken stone beds properly underdrained to provide the maximum nitrifying bacteria. Even this filtrate is not always stable and in many cases carries with it intestinal bacteria in such numbers that sterilization by chlorine or some other method is advisable. It is true that in small plants for private estates or institutions the septic tank with proper diffusion of its effluent through the soil has accomplished a sanitary method of solving problems of that kind.

Many manufacturers of boilers and of concrete wash trays have placed stock tanks on the market with stock rules for installing them and this has resulted in much confusion and misunderstanding in the public mind.

About 1906 Dr. Carl Imhoff, while visiting England, noticed the construction and operation of a sewage treatment tank as developed by Travis, at Hampton, England. This was one of the first "two story" tanks and was planned with sloping partitions so the fresh incoming sewage would settle into a separate sludge compartment. Dr. Imhoff then conducted a most careful study in practical operation of the "two story" tank in the Emscher district in Germany. He made modifications in design which had the specific purpose of separating the sewage of the upper compartment from the sedimentation chamber below and keeping out the gas. This was accomplished by pro-

viding a slot in the upper hopper bottom six to twelve inches wide and an overlap of three inches or more measured horizontally. This detail alone distinguishes the Imhoff from the Travis tank. Soon after this period Dr. Imhoff came to the United States and his plans were approved by Mr. Rudolph Hering, the dean of sanitary engineering in this country. From then on this type of tank has been most popular with American engineers. There are many cases, however, where even now it is expedient to use the older one story type together perhaps with a separate digestion tank, or arranged in two or more units so one section may be shut down and allowed to act as a digestor. All types of tanks are subject to modification in their design due to the characteristics of the sewage and its rate of flow.

While much attention was being given to the biolytic tank, yet many engineers were working on screens, separators and other mechanical contrivances which they believed would solve their problems. The patent office is full of drawings of accepted patents on mechanical contraptions most of which have never proved of any great value.

The chemists, too, have taken a large part in the successful development of the art. Much money and thought have been spent on experiments and a number of chemical and electrochemical plants have been built.

The use of lime as a precipitating agent was one of the first and most successful methods used. The process involved the removal of large volumes of sludge which was very hard to dry and difficult of disposal. It had no value as a fertilizer unless mixed with other substances which made the cost too high to be of any great commercial use. The run-off or effluent from these plants was apt to be much discolored and would deposit lime to a noticeable degree in the stream beds. Then also the effluent was so "strong" in chlorine and in lime deposit that it seriously interfered with fish and all other living organisms. The use of electricity was introduced in conjunction with lime as a precipitant and the system was described as an electrolytic process. Experiments showed, however, that the electric current was of little or no value and the cost very high.

At all times bar screens have been used and are of great value in the removal of rags, sticks and other inorganic materials which find their way into the sewers. The fine revolving screens have also been of great help in removing smaller particles. They are particularly helpful in industrial plants, such as tanneries, paper mills and the like, where they can be operated by skilful and interested men. Any screened sewage can of course be treated in tanks just so much more easily. The removal of "screenage" from the screens is accomplished under hand or power operation, depending on the size of the plant and the type of screen in use. This screen product also offers a difficult problem, as it requires dewatering by drying or centrifuging and its ultimate disposal must be by incineration or burial.

The complex nature of sewage treatment caused more and more study along lines leading to rapid oxidation of the sewage water and rapid removal or separation of sludge. The so-called activated sludge process is now quite highly developed, and this type of plant is now approved by engineers of the highest standing. The process as a rule is made up of:

(1) A grit chamber with a coarse screen for the removal of very large objects which may come through the sewers.

(2) An aeration tank in which sludge is activated by aerating sewage for time enough to permit the solid particles to be impregnated with oxidizing bacteria. This is a biochemical process in which the activated sludge is mixed

with the sewage to be treated for a period of from two to four hours.

(3) A sedimentation tank where the effluent from the aeration tank is allowed to remain for half an hour or longer, precipitating its activated sludge. A proper portion of this sludge is then returned to the aeration tank and the excess deposit is withdrawn for drying. The effluent from the sedimentation tank passes off clear and well purified. The sludge as activated is produced by agitating the incoming sewage with air until it has a flocculent appearance. This flow will settle rapidly and contains aerobic bacteria in such numbers that they may be quickly imparted to the sludge of the raw incoming sewage.

(4) A sludge digestor tank or secondary sedimentation chamber is a feature included so that the accumulating sludge removed from the incoming sewage may be properly brought to a condition where gassing stops and it becomes ready for dewatering by drying on beds or with other mechanical means. It is this final product which is used as the base of fertilizer.

A well-designed and operated plant will produce a clear and non-putrescible effluent. There is, however, some division of opinion as to the costs of plant installation and particularly the operating costs.

The most outstanding example of activated sludge plant is at Milwaukee, and much data are available on the results obtained there. The question of the cost of operation and income from dried sludge as a fertilizer has caused much discussion.

There are a number of plants operating in the United States, and the Ward's Island plant for a portion of the City of New York is now under construction. This will treat a sewage flow of 180 million gallons per day and will cost with its collecting works about $30,000,000.

The science is progressing rapidly and it is quite within reason to expect that within another ten years engineering and chemistry will have so improved the plant design that sewage will be treated at much higher rates of flow and at much lower costs both in the original construction and in the operation.

The last thirty-five years just about covers the entire development of sewage treatment in this country. We have made a somewhat slow progress due to the difficulty in arousing public opinion as to the great need of adequate sanitation and the protection of our rivers and lakes.

It is now quite generally understood that the protection of a town's citizens against disease is more important than any other public act its government may make. Sanitary treatment of sewage also helps much in the reduction of cost of living by the increased freedom from disease and offense which our streams when sewage polluted so often caused.

# ENVIRONMENT AND THE STUDENT OF HUMAN GEOGRAPHY

By Dr. DERWENT WHITTLESEY

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To the average American, living carefree in his vast continent and careless in his use of words, "international" connotes a kind of cosmopolitanism in which all national bars are thrown down.

That even the genial warmth generated by mutual scientific endeavor is not able to melt away every-day nationalistic attitudes is the discovery every student of human geography makes when he explores the output of his coworkers of other lands. Geographers, it seems, like the subject they profess, are inextricably tied into the environment in which they work. If we cast up the accounts for regional studies alone, or if we consider the whole output of different national (or rather linguistic) groups of geographers, we discover telling contrasts between them.

Students of human geography in large enough numbers to provide a basis for generalization exist in Germany-Austria, France-Belgium, the British Isles, Scandinavia (chiefly Sweden) and the United States.

Of these groups, the Germans have been working longest and have amassed the largest bulk of material, the product of the largest number of minds and pens. German geography has consisted of two related but distinct series of studies: contributions to physical geography and contributions to human geography. Having grown out of geology in Central Europe, physical geography bears the well-disciplined form of the older subject and in effect stands as a branch of it. Human geography, as expounded by Germans, is more miscellaneous in character, and it is almost chaotic in its organization, since there is no agreement as to the order of items to be discussed, nor even as to the topics themselves. In this general field, however, German geography has been given special color by its preoccupation with political conditions. The only periodical devoted wholly to political geography is a German publication, and, among treatises on political geography written since the war, an overwhelming majority have been by Germans. This will cause no surprise to the geographer who recognizes the profundity of the age-long struggle between the Germanies and their neighbors, most of them enemies or potential enemies, who nearly encircle the lands of German language and culture.

British geography emphasizes the physical aspects of the subject, particularly geomorphology, sometimes to the exclusion of human geography. In this it strikingly resembles German work, although it is narrower in scope in that it typically omits biogeography and soil and minimizes climate. Like the Germans also, British geographers have engaged in discussion of political phases of the subject. It would be strange if so preeminent a political power as Great Britain has long been did not manifest this interest. But the number of books and articles published has been only a meager fraction of the German output. British human geography has concerned itself primarily with commercial topics, *i.e.*, with the geography of world trade, to which is articulated a study of commodities produced in various parts of the earth. This is precisely what should be expected from a people whose major

business for 300 years has been the exchanging of products from all parts of the world and provision for their transportation. In this restricted and therefore relatively simple branch of human geography, British work is coherent and systematic, although perhaps perilously close to economics.

The French school of geography, although in its origin the child of history rather than of geology, has come to essential agreement with the British and the Germans as to the independent and significant place which should be accorded to physical geography, or at least to that part of it which concerns landforms. The glory of the French school, however, has been the explanatory description of regions, and geographers of all other countries have found their models for regional geography in the writings of French geographers. Here, again, the trend of thought closely parallels environmental conditions. For many decades France has been relatively free from political stress, either with her immediate neighbors or in her colonial empire; at the same time she has had only moderate commercial interests. As every traveler in France knows, however, France is the land *par excellence* of sharp regional contrasts. In fact, it is strikingly an aggregation of *"pays,"* each of which has its distinctive character stamped upon every aspect of the natural environment and upon every form of human occupance thereof. What more natural than that French geographers should early turn their attention to interpretative description of these regional entities which constantly meet the eye and by their unity seize the attention?

In these three major European language groups have grown up the three initiating schools of geographic thinking in its current manifestation.

To the United States geography first came as a revelation from Great Britain, an event inevitable since books and articles written by British geographers, including text-books, are an open sesame to English-speaking North Americans. Hence the beginnings of human geography in the United States were markedly colored by the commercial thinking dominant in Great Britain. Promptly, however, commercial geography expanded under the genial stimulation of America's enormous unexploited natural resources. It was only a short step from the consideration of trade fed by commodity production, to a study of commodity production facilitated by trade; or, to put it in terms of text-books, American commercial geography rapidly expanded into economic geography.

Coeval with its rooting in British commercial geography was the shoot which geology put forth to make of geomorphology an important part of geography in America. Grafted upon the geographic plant, this branch throve, and with later graftings of climatology, pedology and plant ecology formed a flourishing tree. American geography, however, has not confined itself to the physical and economic phases of the subject because, like everything else in American life, its geography is eclectic. American students have therefore delved into such diverse subjects as political and historical geography, regional geography, conservation of natural resources, cartography and soils. This rambling about the field has kept American geography immature, and at the same time flexible and open to new ideas, including recently some of its own invention.

In Scandinavia geography has likewise been eclectic, but here with the unweighted choice natural to people who share equally, as second languages, all three of those in which human geography first received expression. In view of British and German precedents, physical geography naturally takes its accustomed place. Human geopraphy is by no means shoved into the background, however, and in this field workers lay al-

most equal emphasis upon economic, political and regional study. This seems to be explicable enough in an area of large resources, marked political subdivision and contrasted geographic regions.

If we narrow the discussion from geography in general to that part of the study which by common consent seems to be thought of as its core, namely, regional geography, we reduce the scale of the picture, and at the same time bring our different schools into the same focus.

In treating regional geography we should expect the French to excel, a natural consequence of their early start and assiduous prosecution of regional studies. They have evolved a clear-cut technique, including reconnaissance, field work and well-knit presentation. With a few shining exceptions, the Germans have been left far behind, except in dealing with states as regions. The British likewise have not as yet found themselves in regional geography, except for a small number of workers who have felt the repercussion of thought from French or American shores. The Scandinavians, as might be expected, have seized upon the regional idea with more success. In particular, they have passed their geographic materials through the refining flame of an illuminated cartographic discipline. As they have only lately entered this field, their output is as yet small.

Recently, American geographers have introduced modifications of the regional concept of the Europeans, whether for better or worse time will tell. Europeans, especially the British, have tended to lean heavily upon the superb government maps at their command. Since the best official maps are invariably geomorphic at heart, their users have naturally stressed land-forms. Americans, lacking adequate maps for much of the vast, undeveloped country about them, have been compelled to tackle the field directly as a fresh problem. The construction of maps inherently geographic became for them a primary requisite of field study. The immense labor imposed by this cartographic problem confined studies to diminutive areas, with the result that details have multiplied. Putting these details into the picture has thrown new light on the larger subject of regional geography. The American view-point of regional geography has come to be, ideally, that of a balanced and undivided study of areas (in all their physical and biological aspects) and the human occupance thereof (economic, social and political).

One of the most significant trends in geographic studies is the *rapprochement* between the several schools of thought which has occurred during the last decade. Possibly, after all, there awaits around the corner a cosmopolitan school of human geography.

# SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

## THE CONQUEST OF DIPHTHERIA

By Dr. A. W. FREEMAN

SCHOOL OF HYGIENE AND PUBLIC HEALTH, JOHNS HOPKINS UNIVERSITY

THE conquest of diphtheria, like other important advances of science, has not come suddenly or as the result of a single brilliant achievement. It is the result of more than a century of effort by hundreds of men working in every part of the civilized world. To tell the complete story of its development would be to write the history of science for the past hundred years. Every important advance in science in that time has yielded something of value in the solution of the problem of controlling diphtheria. Without this general advance of science, the disease could never have been controlled.

Diphtheria is an old disease, probably older than any human record. It has prevailed almost all over the world, sometimes in devastating epidemics, sometimes as a constant menace to child life in settled communities. It has been one of the major scourges of childhood. It is always a serious disease. Even when the patient recovers it often damages the heart or kidneys beyond repair. The laryngeal form of the disease, sometimes called membranous croup, is one of the most terrifying diseases to which humans are subject.

In spite of the serious nature of the disease, and of its long and wide-spread prevalence, it was not accurately described and given a name until about 1820, when a French physician, Bretonneau, was able to distinguish it from other affections of the throat and to give it a place as a definite and recognizable disease. This first step was most important of all. Until it had been taken, nothing else of value could be learned about it. Half a century had to elapse after Bretonneau's work before anything more of real importance was accomplished. Science was not yet ready for the solution of the problem. Pasteur had to be born and to grow to maturity before the next step could be taken. The doctrine that living things come only from previously living things had to be established in men's minds. The fact that certain diseases are caused by the entrance into the body and growth there of microscopic living bodies, popularly called "germs," had to be proved and accepted before further fruitful work on diphtheria could be done.

Once this fact was proved, however, it was not long before diphtheria was added to the list of diseases caused by germs. Klebs, a Swiss physician, in 1883, saw under the microscope and described accurately certain very small rods which he took to be the living organisms causing the disease. In the following year, Loeffler, a German, finally settled the question of causation by cultivating these organisms outside the body and proving their connection with the disease. Bacteriologists everywhere confirmed this discovery, and it was soon possible to cultivate the organisms with ease and certainty and to distinguish them from all other known bacteria. The organism was named officially the bacillus of diphtheria, but it soon became known as the Klebs-Loeffler bacillus, in honor of its discoverers.

Once these discoveries became known it was thought that the conquest of diphtheria was at hand. Knowing the

cause of the disease, able to determine by microscopic examination whether or not a given case were diphtheria, certain of the means by which the bacilli left the body, and knowing how easily the bacilli might be destroyed, surely one had reason to believe that the disease might be controlled or even finally eradicated.

Unfortunately, the problem did not turn out to be so simple. Even after all known cases had been isolated and all infectious material destroyed or made harmless, cases of diphtheria continued to appear. Many cases proved on investigation to have had no connection with any previous known case of diphtheria. Many cases occurred far from any previous case. The riddle was soon explained. Diphtheria bacilli are not confined to the throats of people who have diphtheria. Of any thousand healthy people examined, a certain number will almost always be found to harbor diphtheria bacilli in their throats. These persons are able to infect others, though not themselves harmed by the presence of the organism. Why, of two persons similarly exposed to infection, one should become a case and another a carrier could not then be explained. In any event, isolation of the known cases, however perfectly carried out, would not alone control diphtheria. Isolation of all carriers was out of the question as a practicable procedure. Other means of prevention must be devised.

Light began to come from a new quarter. Roux and Yersin, in France in 1888, discovered that the diphtheria bacillus possessed a peculiar property, shared only by one other organism known at that time. When grown under certain conditions in the laboratory, it produces a most powerful toxin or poison. This discovery explained many puzzling things about the effect of the disease on the patient, but it did not immediately help in prevention.

Others, however, had shortly before discovered that when certain plant poisons are injected into animals, beginning with small doses and gradually increasing the amount, in time the animal can take, without injury, an amount many times what would at first have been fatal. Furthermore, the blood of the animals so treated acquires the power to neutralize the poison when mixed with it. The same thing had been found to be true with regard to the venom of reptiles. Protective serums against snake-bite so prepared had already proven their value. Behring, a German scientist, proceeded to experiment with the toxin of diphtheria in the same way. After a time he succeeded in producing a serum which would actually neutralize the toxin. This serum, diphtheria antitoxin, was perfected in 1890. It soon came into general use in the treatment of diphtheria, and its results are almost miraculous. A child infected with diphtheria may be poisoned to the point of death by the toxin produced by the bacilli growing in the throat and absorbed by the blood. When injected promptly with a sufficient amount of antitoxin, improvement is almost immediate and recovery usually follows promptly.

Treatment with antitoxin within a few years reduced the number of deaths per hundred cases from forty or more to less than ten. The total number of deaths, therefore, promptly decreased and has never since approached the old figures. The number of cases, however, remained high, even though it was soon found that if a child had been exposed to diphtheria a small dose of antitoxin would prevent the development of the disease. This protection lasted only a short time, however, and antitoxin could not therefore be used to protect the whole population. More knowledge was needed.

There was a gap of nearly twenty-five

years between the discovery of antitoxin and the next forward step. In that time all known means of preventing diphtheria were used, but the results were disappointing, and health officers everywhere were quite pessimistic as to the possibility of real control.

In 1913, Schick, in Vienna, adapted to diphtheria a method which has been used in the diagnosis of other diseases. Injecting into the skin of the arm a very minute amount of diphtheria toxin, he was able to determine from the reaction, that is, the amount of irritation and reddening which occurred about the site of the injection, whether or not the person possessed resistance to diphtheria. This test was of interest, but its practical value was not immediately evident.

The next and final step, however, was not long delayed. Park and Zingher announced in 1920 that after a long series of experiments they had succeeded in mixing diphtheria toxin with antitoxin in such a way that the mixture, which they called toxin-antitoxin, or familiarly T.A.T., could be injected into human beings without harmful effect, but with the result that the person injected would in a short time develop a resistance to diphtheria sufficient to protect him from infection. So, at long last, the conquest of diphtheria became possible.

Before toxin-antitoxin could be applied practically, however, much more work must needs be done. The laboratory workers had forged the weapons, but before they could be used, means of applying them to field conditions must be devised. The use of the culture for determining the presence of the organisms and of the Schick test for indicating the existence of immunity made the field studies of diphtheria far more accurate and revealing than had previously been possible. Many problems which had previously been incapable of solution were cleared up by these means. From these studies it became clear that diphtheria infection is constantly present in most large communities and that diphtheria bacilli pass readily from person to person. Most city dwellers are repeatedly infected during their lives. Infection early in life or with a large dose of an active culture tends to result in disease. Infection later in life with a small dose of a less active culture not only does not usually produce disease but may actually raise resistance. Most city people have, by repeated exposure to these mild infections, acquired an immunity before they leave school. The fact that diphtheria is more prevalent in childhood is due probably more to the absence of resistance than to the greater infection. Infection is much less common in rural areas than in cities, and resistance comes later if at all. In cities the children of the more crowded areas develop resistance sooner than the children of the well-to-do. Observations such as these clarified the knowledge of the spread of the disease and enabled the new measures of prevention to be applied with efficiency and certainty.

Careful studies had been made as to the ages at which immunization with toxin-antitoxin should be done, the size and frequency of the doses, and the number that must be immunized to secure significant results. Methods of getting people to consent to be immunized and the organization of campaigns for the immunization of school children and of young infants were worked out. These methods have been applied on a large scale only for the past seven or eight years. Hundreds of thousands of persons have now been immunized, and results are beginning to appear. New Haven, Connecticut, a city of 162,000 population, has been three years without a single death from diphtheria. Other cities have done almost as well. Diphtheria death rates have been reduced in almost every state in the Union.

Immunization against diphtheria by toxin-antitoxin has been proved beyond doubt to be safe, effective and capable of general application.

Within the last few years another modification of diphtheria toxin, called "toxoid," was discovered by Ramon. Toxoid is especially suitable for the immunization of infants and children under six and is now generally used instead of toxin-antitoxin for that group.

Using the Schick test to control both the need for and the effect of immunization, almost any individual or any community can now be protected against diphtheria safely and at reasonable cost.

Diphtheria can probably never be eradicated. The fact that it is transmitted by the secretions of the nose and throat and the further fact that the ability of healthy persons to carry the organisms is not affected by immunization would seem to indicate that the organism will continue to exist indefinitely. Protection by immunization is almost everywhere available, however, and the control of diphtheria is a possibility entirely within our reach.

# TREE CROPS FOR PAPER MAKING

By Dr. RALPH H. McKEE

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THE talk to-day will present to you a picture of this country's need of more raw material, that is, trees, for paper-making and their possibilities as a farm crop. Most of us take the enormous quantities of books, magazines and newspapers for granted. Paper for them is made from wood which is cut and treated to make paper pulp. I am speaking from New York City. Each week the newspapers of this city use all the paper that can be made from the wood cut on ten thousand acres of pulpwood land. The books and magazines printed here use about as much more each week. If that twenty thousand acres of land is allowed to reforest naturally it will be sixty years before it is again ready to cut. Then it will yield the same amount of wood as before.

It is not generally realized how rapidly the supply of pulpwood in the United States is decreasing. We are now cutting pulpwood about four times as fast as we grow it. The lumber industry also is cutting trees more than twice as fast as we grow them. However, due to special requirements for pulpwood, the reserve is smaller and the shortage will first be severe in the paper industry. Even now more than 50 per cent. of the paper used in the United States is made from foreign-grown pulpwood.

China, Australia, South Africa and the United States are heavy importers of wood. Two thirds of the states of this country are using more wood than they grow and are on the road to forest bankruptcy. Eighty years ago New York and Pennsylvania were the leading wood-producing states. Now they supply only 4 per cent. of what they use. If wood starvation is to be kept at bay we must immediately adopt and rapidly extend the idea of trees as a crop.

Nowhere among the wild trees do we find a combination of all the qualities necessary for such a purpose. The wild trees have been growing as pure species for many centuries. That is to say, they have been inbred and hence deteriorating these thousands of years. It is common knowledge that certain animals and many agricultural crops have been improved, or desired characteristics developed, by cross-breeding, that is, hy-

bridizing. Some familiar examples are the mule, which is a cross between the jackass and the horse; the loganberry, which is a hybrid between the Antwerp red raspberry and the ordinary blackberry. Hybrids, as a rule, grow faster, are freer from disease and, in the case of animals, eat less than either of the parents. Unfortunately they do not breed true, that is, loganberry seeds when planted will grow into raspberry and blackberry plants. It was to be expected that trees might be improved by controlled hybridizing, as had been done with so many smaller plants.

Do ordinary trees grow fast enough to be considered a farm crop? No, they do not. Trees are usually measured at breast height. A spruce eight inches in diameter at that height is about ninety years old. A white pine of the same size is seventy years old and an ordinary aspen or poplar, which is used to make paper for books and magazines, is forty-five to fifty-five years old.

What characteristics will be most desirable in trees to be planted as a farm crop and to be used for paper-making? They must grow rapidly. They must be free from diseases. They must have a large, tall, straight trunk with few branches. They must grow well on poor grades of land without fertilizer or cultivation. They must be propagated by cuttings rather than from seeds. The wood must be light in color and the individual fibers must not be shorter than those of woods now used for paper-making and lumber.

With others I have been working on this problem for a number of years. As subjects I chose trees of the poplar family, because they already had some of the characteristics I wished to develop. For example, cuttings of the hybrid poplar called the Carolina poplar (sometimes incorrectly North Carolina) and known to botanists as *Populus Eugenei* will grow into trees with a diameter of eight inches in twenty instead of fifty years. About the only requirements for rapid growth of this variety are sunshine and moderate rainfall in each of the months of May, June, July and August. The slash pine which grows in the South will do fully as well as the Carolina poplar. However, it could not be used to advantage in the whole country, as it does not grow well north of Georgia, whereas the poplar is at home North and South.

During the past several years we have hybridized selected poplars and grown some fifteen thousand seedlings, from which we kept the fastest growing individuals. We now have a number of new hybrids that grow more rapidly than any variety of tree now used for pulpwood or lumber. We have every reason to expect that the new hybrids will give us an eight-inch tree in ten years—a fifth the growing time of the ordinary poplar, or half the growing time of the Carolina poplar. The quality of the wood apparently is not adversely affected by the rapid growth. Indeed, the fiber tests even better than that of wild poplar.

The parent wild poplar trees grow less than two feet in height a year. The better varieties of the new hybrid poplars add between five and six feet in height a year. In the particularly favorable season of 1931, I had four especially vigorous trees, each of which grew nine feet six inches in the growing months of May through August. However, that is better growth than is to be expected in a normal year. Under the present patent law, new hybrid plants can be protected by patent. The law applies to trees as well as to smaller plants, and so patent applications have been filed to cover the new hybrid trees.

In Italy and France many acres are planted with Carolina poplars for the production of lumber. The profit of such plantations compares favorably with similar acreages planted with wheat or corn and the soil need not be

nearly so rich. In these days of surplus farm crops farmers should plant their less productive lands, if well-watered, with trees.

Timber has a diversified market, both as lumber and as pulpwood. It has the further advantage that tree crops can be left growing until wanted. Instead of spoiling like a forage crop, they increase in size and value. It is not necessary to market the wood when the price is low. We have every reason to expect greater returns per acre per year from trees as a farm crop than from wheat or corn. Most states now free reforested areas from taxes until the year the trees are cut. This tax exemption for the period of growth is a great help and should be an inducement to farmers to grow trees.

My suggestion is to plant such trees as Carolina poplars or slash pine now. They will make a profitable crop in most localities, even though the farmer has to wait a number of years before he cuts them. The experience gained in planting and handling these trees will permit him to embark with every assurance of success on cultivation of the new and still faster growing hybrid poplars when their cuttings become generally available a few years hence.

Can farmers grow crops of trees? They can, indeed, and profitably.

# THE PROTECTION OF OUR NATIVE FLOWERS

By P. L. RICKER

PRESIDENT, WILD FLOWER PRESERVATION SOCIETY

Few people who have not seen the wild riot of color still to be found on some of our Western plains and mountain meadows can form any idea of the wealth of flowers that must have greeted the early settlers of this country. The places in the East where such displays can still be found are very few, compared with the West, and in all sections of the country they are becoming fewer each succeeding year. The present scarcity of wild flowers is due largely to three causes and over the first two of these little or no control is possible. These causes are: (1) the clearing of land for agricultural purposes; (2) real estate developments for small homes; and (3) fire.

In the early days the settlers found it necessary to cut down trees and clear the land to establish small farms. These have been increased in size by further cutting, and in the more densely populated districts the few remaining woodlands and fields are being rapidly destroyed by real estate companies for small home developments. In many such cases all trees are cut down, hills are leveled and the soil dumped into the hollows to secure level ground. The resulting homes are left exposed to the scorching sun, with few or no trees to shade and make them more attractive. The once rich surface soil, containing humus from the decay of leaves for countless years, is usually buried and the resulting subsoil surface is little suited to the use of the home seeker, without years of patient work of restoring fertility.

Before the advent of man in this country, forest fires were set by lightning as they still are occasionally. The Indians first set fires to clear the land to cultivate maize and then to establish hunting grounds for the buffalo. That our Western plains states once bore an abundant forest is attested to by the finding of buried trunks of fossil trees. From the early burning of land for

clearing purposes there has persisted a tradition that the burning over of pasture and hay land every fall or spring is a necessity in order to liberate in the ash the fertilizing elements, but what actually happens is that the humus of the soil, formed by the decay of vegetation and the soil bacteria in this humus which do the actual freeing of the fertilizing elements, are destroyed by such fires and the ground further impoverished.

In some parts of the South, this burning has been so consistently practiced that both the roots and seeds of the attractive wild flowers have been destroyed to such an extent that the flowers are rarely seen. In other parts of the country the land has been so completely taken up for farm purposes that I was informed by a Pennsylvania farm-raised girl applicant for coloring lantern slides of flowers that she did not think there were any wild flowers in Pennsylvania.

The thoughtless throwing aside of cigarette and cigar stubs and pipe cleanings, the leaving of unquenched camp fires in the woods by hikers, picnickers, sportsmen and campers, causes hundreds of serious forest fires every year, destroying the very flowers, trees and game that brought them to the woods, and causing more landowners to bar such use of their woods each year. Be sure your ashes and stubs are ground under foot until out and your camp fires wet down and buried, if you want to continue to use these woods.

No species of wild flower is found in all parts of the country, and a species that is very rare in one part of the country may become very abundant in another part not more than two hundred to three hundred miles away. This is well shown in the rapidly increasing abundance of the mountain laurel from Maine to the mountains of North Carolina, where it makes its most wonderful floral display. It even happens that a flower that is abundant in the northern part of a single state is rare in the southern part or *vice versa*, and the same may be true between adjoining counties or from the top to the bottom of a single mountain. The problem of deciding just what wild flowers need protection and what ones do not is therefore decidedly complicated.

A safe rule to follow is that no attractive wild flower, except the well-known weedy ones, should be picked for bouquets, unless there are at least one or two hundred of them, and then pick not more than one out of ten flowers. The spring flowers that grow in the woods are also the ones most in need of protection. A much larger proportion of the summer and fall flowers grow in open fields and along roadsides, have more aggressive root and seed habits, and as a general rule, where abundant, may be picked freely with little danger of extermination.

In many of our largest cities there are countless thousands of children who have never seen any of our native wild flowers, and in the smaller cities, where there may occasionally be a vacant lot, their vision has been limited to the flowers of such weedy, wind-borne seeds as the dandelion, thistle, wild lettuce, ironweed, chicory, goldenrod and jo-pye-weed. Most of them have heard of that elusive fragrant beauty—the trailing arbutus—but few children, except those living in the country, and few adults, unless country-born, have ever seen it. It is extremely difficult to grow from roots, even in acid soil, but it grows from seed much more readily.

Even more elusive is the beautiful fairy slipper orchid Calypso, named for the nymph who tried to "vamp" Ulysses, and found in the cooler bogs of both continents. Recently a Northern lady of nearly threescore years, who has traveled extensively, came to my office for help in finding a place to see

it, and stated that she and her mother, a college professor of botany, who had recently died at advanced years, had sought it in vain all their lives. Most other orchids, while not so rare, should be protected. Few can be grown from seed or roots under ordinary garden conditions. Another nearly as elusive flower is the fringed gentian, which is rarely found, except in cool, damp meadows of the East and mountain meadows of the West. It can not be cultivated in garden soils without providing its native conditions, and then only from seed in the case of the Eastern species, which is a biennial.

In some of the Middle Western states the railroad right-of-way and the roadsides furnish about the only view that the average city-dweller of the region can obtain of wild flowers, and some of these displays are often very attractive. They, however, often include bad weeds, to which the farmer objects, and the railroad finds them a serious fire menace; so that many of these sources are now annually cut or burned one or more times every year.

A few railroads at higher elevations and with less weedy subjects have used the color display in their advertisements to induce nature lovers to use their line, and one railroad has one of its dining cars named and service and menu decorated with a blue columbine motif, and a request to "Hold sacred that which is beautiful." This attractive flower is the state flower of Colorado and has been ruthlessly destroyed in many places by too much picking, but in the more inaccessible places it is still found in abundance. In California the native poppy, which is the glory of the fields, is rapidly decreasing in abundance. In the Southwest many species of cactus, which were thought to be proof against extermination, are now being commercialized to such an extent, for gardens, confections and recently the juice as a reputed preventive of scale in boilers, that their existence in many localities is seriously threatened. Very few plants have as attractive flowers as the cactus, and a tree cactus species is the state flower of Arizona.

Laws for the protection of some of the rarer wild flowers have been passed by twenty-two states, but there is very little enforcement in any of them. If enforcement is really desired, the common law covering trespass and theft is sufficient for making prosecutions without unnecessarily encumbering the statutes with further laws of doubtful value. Education in the schools is one of the most effective methods of protecting the flowers still remaining, supplemented by newspaper and magazine articles, motion pictures and colored lantern slides with lectures.

Where they can be given adequate protection, permanent wild flower sanctuaries should be established, but without protection, fires, picking, digging up plants for private gardens, and picnic refuse will soon make them look as bad as the average city dumping grounds. It is the desire of the Wild Flower Preservation Society to obtain land and funds for establishing such protected sanctuaries where with expert supervision many of the flowers can be sufficiently increased in abundance to enable distribution of some of the rarer species to protected areas, where they are adapted but are at present rare or little known. Circulars on the need for wild flower protection, and listing as well many of those that may be picked freely, with directions for cultivation and list of seeds available, may be obtained free by addressing the Wild Flower Preservation Society, Washington, D. C.

# CHEMICALS MAKE FIRE-FIGHTING DANGEROUS

By LIONEL K. ARNOLD

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WE are living to-day in a chemical age. No where is this more apparent than in fire-fighting. Not so many years ago fire-fighting was merely what the name suggests, fighting fire. If you could get enough water on the blaze it was out and that was about all there was to it. Of course, there were always the hazards of falling floors and walls and the danger of being overcome by smoke but these dangers seem trivial compared to those introduced by the modern widespread use of chemicals. One of the peculiar hazards introduced by the chemicals is that of uncertainty as to what to expect. The introduction of new chemicals into common use forces the fireman to always be informed upon new industrial chemical uses in order to keep abreast of the times.

Various hazardous gases have come into such common use as to present definite hazards to firemen. These gases may be poisonous, explosive, or merely inert. They are commonly shipped and used in heavy steel cylinders ranging in size from the so-called "lecture bottles" 14 inches long by 2 inches in diameter to the one-ton chlorine cylinders which are 80 inches long by 30 inches in diameter. These cylinders (Fig. 1) are strongly constructed and fitted with carefully inspected valves so that the hazards arising from normal use are not great. The high temperatures occurring in fires cause a tremendous increase in pressure which, if not relieved, may burst the cylinder. To guard against this the cylinders are equipped with fusible safety plugs (Fig. 2) which melt at 150° F. allowing the gas to escape. Unfortunately, the temperature is frequently so great that the increase in pressure can not be prevented by the use of such a small opening and the cylinder bursts with explosive violence. Whether the

FIG. 1. VARIOUS TYPES OF GAS CYLINDERS.

LEFT TO RIGHT: ACETYLENE, CARBON DIOXIDE, OXYGEN (SIMILAR TO CYLINDERS USED FOR AMMONIA AND CHLORINE), OXYGEN WITH PROTECTING CAP USED IN SHIPPING, ACETYLENE.

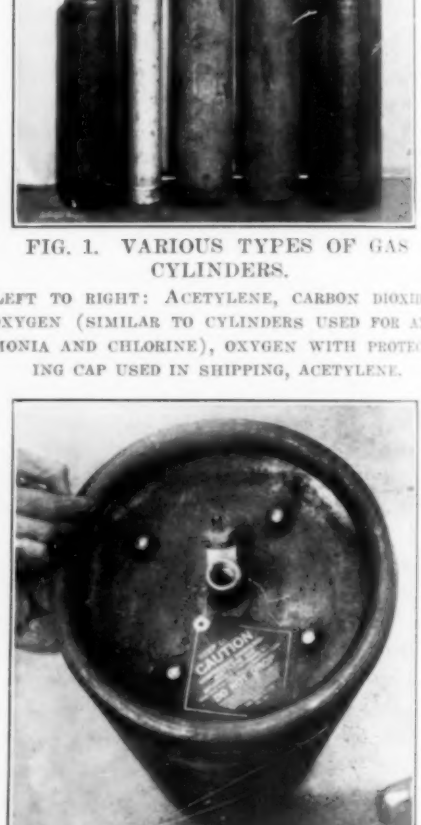


FIG. 2. FUSIBLE PLUGS IN AN ACETYLENE CYLINDER.

THE FUSIBLE PLUGS ON THE OXYGEN AND SIMILAR CYLINDERS ARE ON THE SIDE OF THE VALVE OPPOSITE THE DISCHARGE OPENING.

cylinder bursts or the gas merely escapes through the safety opening the hazards of the specific gas are introduced into the fire unless the cylinders can be removed before the fusible plug melts. Frequently after a fire has been extinguished there will be present gas cylinders which are leaking from the safety openings. Sometimes it is possible to plug these openings with a wooden plug which when wetted swells to a tight fit. Cylinders plugged in this way should be hauled to a suitable dumping place and the gas allowed to escape where it will cause no injury. If a poisonous gas, it should be handled with great care only by men equipped with gas masks. Care should be taken that no hazard to life is caused in the release of the gas. For example, if chlorine is released along a stream, being heavier than air, it may follow along the valleys filling them far downstream with concentrations sufficient to be serious to man or beast.

Some of the poisonous gases available in cylinders are chlorine, ammonia, sulphur dioxide, hydrogen sulphide, hydrogen cyanide, phosgene, methyl chloride and carbon dioxide. Cylinders of chlorine may be encountered in paper mills, water-works and swimming pools. Sulphur dioxide is used in mechanical refrigerators, in fumigation, and as a bleaching agent. Much of it used in factories is produced by burning sulphur although considerable is shipped in cylinders.

Ammonia is commonly used in large mechanical refrigeration installations and cold storage rooms. Hydrogen sulphide is commonly made as used although some of it is shipped in cylinders. Hydrogen cyanide is used as an insecticide and in fumigating buildings. Phosgene is used mainly in dye works. Methyl chloride is used in household mechanical refrigerators. Carbon dioxide is ordinarily not considered dangerous but is poisonous when present in sufficient quantities. It is used in refrigerating equipment, soda fountains, and bottling works.

Flammable gases which introduce explosion hazard into the fire include acetylene, hydrogen, ethlene, ethyl chloride, and various compressed cooking gases. Acetylene is used mainly for welding (Fig. 3) and is commonly found

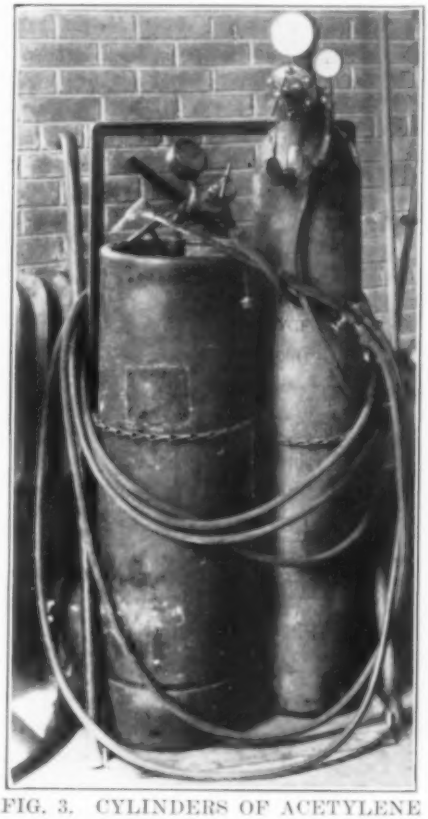

FIG. 3. CYLINDERS OF ACETYLENE AND OXYGEN USED FOR WELDING.

in machine shops, metal working factories, garages, and all other places where welding is done. Hydrogen is used for welding, hardening vegetable oils, and filling balloons. Ethylene is used in welding, in medicine, and for ripening citrus fruits. Ethyl chloride is used in medicine, dentistry, as a solvent, and in household electric refrigerators.

Various other gases such as nitrogen

and helium which present no poison or explosion hazards are available in cylinders and present the danger of possible explosion because of rapid heating. Oxygen, which is used in welding, will increase the combustion rate of a fire.

Gases are only a few of the chemicals in common use. The liquid acids such as sulphuric, nitric, hydrochloric (muriatic), and acetic acids are commonly shipped and stored in glass bottles and carboys. The carboys are glass bottles (Fig. 4) holding 12 gallons and enclosed

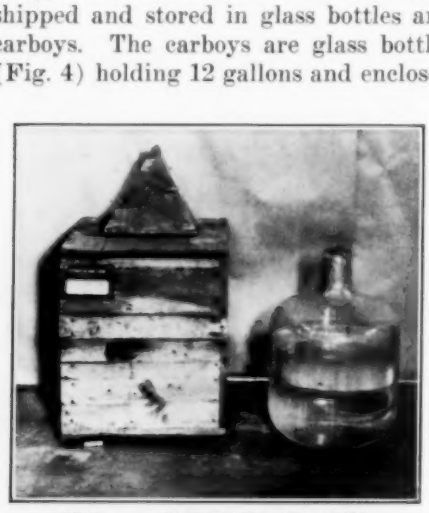

FIG. 4. CARBOYS OF ACID.
LEFT: COMPLETE CARBOY AS SHIPPED. RIGHT GLASS BOTTLE WHICH HOLDS THE ACID.

in individual wooden boxes. Some acids are shipped in special tank cars. There is always danger that the glass containers will be broken by heat, falling débris, or a stream of water from the fire hose. All of these acids are corrosive to the skin. The application of water to strong sulphuric acid may result in spattering the acid over considerable space. The fumes of both hot sulphuric and hydrochloric acid are irritating and poisonous but nitric acid is particularly dangerous since in contact with organic matter and metals evolves the very poisonous nitrous oxide fumes. Dilution with large amounts of water prevents the formation of these gases. These acids are common in drug warehouses and stores, laboratories, and chemical plants.

Various oils and other flammable liquids present hazards which are widespread because of the large amounts sold for automobile use. Small oil fires are readily handled with carbon tetrachloride or foam extinguishers. Large oil fires must be handled according to the individual conditions involved. Special fire-fighting equipment for applying steam, foam, or carbon dioxide to oil storage tanks for fighting refinery fires is largely used. The flammability and explosibility of oils depend upon the volatility of the oil itself and the amount of oxygen present. This means that the explosion hazard varies not only with the oil, but the conditions to which it is subjected. At either ordinary or elevated temperatures the concentration of gasoline vapor in storage tanks above the liquid is too great to be explosive. If the tank is cooled by applying water the concentration may be lowered within the explosive range of between 1 and 6 per cent. The vapor above kerosene and lubricating oils, on the other hand, is usually too lean to be explosive until heated so that it is good fire-fighting practice to cool these tanks with water.

Other hazards of this type are furfurol with about the same volatility as kerosene, benzol similar to gasoline, alcohol about intermediate between gasoline and kerosene and turpentine similar to alcohol.

Solid oxidizing materials such as chlorates, perchlorates, nitrates, and peroxides increase the rapidity of combustion. In contact with organic matter they may cause explosions. Except for the peroxides which are explosive in contact with water these materials may be safely wet down. Water must be kept away from certain metals such as potassium, sodium and magnesium which liberate hydrogen from it, increasing the fire hazard. In the case of the potassium

and sodium the hydrogen bursts into fire spontaneously, spattering the metal over considerable distance. Phosphorus, picric acid and sulphur, on the contrary, should be kept wet down with water.

Various nitrocellulose products such as photo films, moving picture films, x-ray films, and celluloid products on burning evolve very poisonous nitrous oxide fumes. The hazard from this source is possible in such places as moving picture film storehouses, photo supply stores, hospitals, and stores selling celluloid products. The large amounts of celluloid novelties sold in 5 and 10 cent stores gives them a possible hazard rather unexpected in such a type of business. Since the nitrocellulose contains oxygen for its own combustion, fires in it can not be extinguished by merely cutting off the air supply but are most effectively fought by cooling below the ignition temperature by drenching with water.

Even this brief survey which of necessity does not include all hazardous chemicals indicates some of the dangers to the fireman in fighting modern fires. He may be gassed with ammonia in an ice plant, cold storage, grocery, or meat market fire. Even the small electrically operated refrigerators in homes may contain enough poisonous gas to be dangerous. Welding gases in garages and shops offer explosion hazards. Several hospital fires have occurred in which both inmates and firemen have been killed by nitrous oxide fumes from x-ray films. A stream of water may knock enough poisonous chemicals such as bromine or some of the acids from the shelves of a laboratory storeroom (Fig. 5) in a high school or college to be dangerous to all in the room.

FIG. 5. A TYPICAL GROUP OF HAZARDOUS CHEMICALS IN A LABORATORY.

Certain safeguards are available. If the concentration of poison gases is low, a gas mask of the canister type will give protection against poisonous gases and fumes. But in air containing a deficiency of oxygen or more than 4 or 5 per cent. poison gases, dependence can be placed only upon an oxygen helmet. For the most part, the fireman must depend upon his knowledge of the chemicals likely to be involved. For this reason the progressive firemen are studying the chemical hazards which occur. They are familiarizing themselves with the location of all of these hazards in their territory before the fires actually occur.

GRAHAM LUSK

# THE PROGRESS OF SCIENCE

## GRAHAM LUSK

THROUGH the untimely death of Professor Graham Lusk, on July 18, 1932, at the age of 66 years, physiology has lost one of its distinguished devotees, and the science of nutrition, in particular, one of its foremost promoters in America. Born in New England, the descendant of a line of well-known ancestors, he received his collegiate education at the School of Mines, with a degree from Columbia University in 1887. With a chemical training thus secured, he proceeded to Munich to embark upon the study of physiology under the guidance of an eminent master of the science of nutrition, Carl v. Voit. Any one who has heard Lusk discuss his experiences during the four years spent abroad at that time could not fail to realize the profound influence that life and work in the German university exerted upon him and his subsequent career. In after years his publications, his addresses and his intimate conversations abounded in interesting references to the leadership and tuition of v. Voit. Few pupils have retained such supreme devotion to an inspiring teacher.

Equipped with the degree of doctor of philosophy from the University of Munich in 1891, after an examination conducted by the eminent German chemist, A. v. Baeyer, Lusk at the age of twenty-five was placed in charge of physiology at the Yale Medical School in New Haven. At the outset the "department" consisted of one room in an old building. There he began his independent scientific researches; notably, the well-known studies on the action of phlorhizin, affording permanent contributions to our knowledge of the metabolism of carbohydrates in the body.

In 1898, after seven fruitful years, during which he never had a paid assistant, Lusk became associated with the University and Bellevue Medical College, New York City. He was proud of his new affiliation with an institution where his father, Dr. William T. Lusk, an obstetrician of international reputation, had earlier served as dean. After the opening of the Cornell University Medical College in New York City, Graham Lusk became professor of physiology there in 1909, voluntarily retiring from this post at the end of the present academic year in June. Though apparently still vigorous in both body and mind, he had planned to divorce himself almost completely from the active pursuit of his professional interests. In reply to the protests of the writer, he made the characteristic remark, only a few months ago: "I can well recall the words of criticism that I often uttered somewhat violently, when I was in my thirties and forties, about persons whom I regarded as antiquated and reactionary medical teachers of my present age. I shall therefore endeavor to avert a similar fate for myself at the hands of the present-day youngsters, by retiring."

This is not the place for detailed reference to Lusk's scientific contributions to our knowledge of physiology. He was a pioneer in the study of animal calorimetry in this country. The small calorimeter in his laboratory was a research apparatus that has furnished many outstanding facts regarding the fate of the foodstuffs and their derivatives in the living organism. The problems of diabetes, of the specific dynamic action of the nutrients, of the rôle of the amino acids—these and many other aspects of metabolism were attacked with unfailing energy, painstaking technique and unsparing criticism. Lusk's "Elements of the Science of Nutrition," which passed through several editions and was translated into at least one foreign language, has been a standard

text and reference book for many years in all parts of the civilized world. He contributed chapters to various textbooks, including the early "American Textbook of Physiology" and Barker's "Metabolism." The latter contains Lusk's delightful essay on the history of the subject. The "Fundamental Basis of Nutrition," a small volume devoted to problems of diet in wartime, was widely read.

Dr. Lusk was frequently called upon to speak before large audiences. These addresses were prepared with great care. Some of them, particularly in the earlier years of the century, dealt with the reform of medical education and the promotion of research. They were fearless expressions of opinion, usually delivered with the ardent enthusiasm of a crusader. Lusk's intense interest in the promotion of better opportunities for scientific work, the diffusion of scientific knowledge and academic freedom and opportunity in this country and particularly in New York, was unquestionably productive of much good. He was active in the organization of the Harvey Society in New York City and the Society for Experimental Biology and Medicine, likewise originally a local society. To one of his friends he has written: "In New Haven my life was one of peace for seven years. In New York it became one of fierce combat—largely against my father's old friends. But two of these old friends successively stood behind me, Dr. E. G. Janeway and Dr. William M. Polk." The intervening years have indeed witnessed profound changes in the development of the medical sciences in the metropolis.

To Lusk the teaching of students was an engrossing task until the end of his life. There were always a number of advanced workers, including foreign pupils, in his laboratory. The mental discipline was rigorous; his delight in their successes was unfeigned. Among the research students were Howland, Murlin, Ringer, Williams, Wiggers, Edwards, Cattell, Anderson, Gephart, Wilson, Csonka, Chambers, Rapport, Deuel and others whose names have become familiar in physiological literature.

During the world war, Lusk became a helpful adviser to the U. S. Food Administration. In company with R. H. Chittenden he was sent abroad as an American member of the important Interallied Scientific Food Commission, which included T. B. Wood and Starling of England, Gley and Langlois of France, and Bottazzi of Italy.

Early in the history of the Russell Sage Institute of Pathology, Lusk became a member of the board of directors and in turn its scientific director until his death. He was instrumental, notably through the cooperation of Dr. E. F. DuBois, the medical director, in initiating a long series of investigations on clinical calorimetry with the aid of the large respiration calorimeter, built and maintained in Bellevue Hospital, New York City. There many of our fundamental conceptions of metabolism in disease have been established.

Academic honors came to Lusk in liberal measure from many parts of the world. He was an honorary doctor of medicine of the University of Munich; doctor of laws of the University of Glasgow; fellow of the Royal Society of London, and so forth.

Few persons exhibit the singular personal charm that was a much admired characteristic of Graham Lusk. To his friends—and they were many—he was truly a lovable individual. He was a genial host. Many scientists will recall the unbounded hospitality that Lusk delighted to extend upon every appropriate occasion to his colleagues at his home or his club. Thus he enjoyed the privilege of entertaining the foreign members of the International Physiological Congress at his summer home on Long Island in 1929.

A unique spirit of friendliness, combined with dignity and uprightness, suffused his life. He had a fine appreciation of his colleagues; but he hated sham and never hesitated to expose it. Only a few months ago, at the Philadelphia meetings of the Federation of Biological Societies, Lusk made an address that was in truth a valedictory, preceding his retirement from academic life. He attacked with all the vigor at his command certain tendencies in education that he regarded as vicious; then he fervently defended one of his own scientific views that has latterly been questioned; and finally, in a kindly endeavor and in a spirit of calm retrospect, he recalled some of the pleasantries of an exchange of correspondence with his colleagues—a final tribute of an appreciative scientist to the cheerful, human side of life.

LAFAYETTE B. MENDEL

## THE PEARL OYSTER RESOURCES IN THE PACIFIC

IN 1930 the United States Bureau of Fisheries, in cooperation with the Navy Department, who assigned the minesweeper, *Whippoorwill*, to assist in the work, sent an expedition to study the pearl oyster beds at the Pearl and Hermes Reef off the end of the Hawaiian Archipelago.

The expedition was in charge of Dr. Paul S. Galtstoff, who, for some time, has been in charge of the extensive oyster investigations of the United States Government. The official report of the expedition will be completed in August.

The Pearl and Hermes Reef is a small atoll situated about 76 miles east from Midway Island and 1,100 miles west of Honolulu. Since the discovery of Pearl and Hermes Reef in 1822 by two British whaleships which, on the night of April 26, were wrecked within ten miles of each other, but a few persons visited this place. In 1858 Captain Brooks, cruising on the U. S. S. *Gambia*, explored the atoll. In 1867 it was surveyed by U. S. S. *Lackawanna*. Then it was visited in 1912 by a German engineer, Elschner, engaged in a study of phosphate rocks of the Pacific; and in 1923 by Dr. Wetmore, of the National Museum, in charge of the *Tanager* expedition. In 1927 extensive pearl oyster beds, discovered on the reefs of the lagoon, attracted fishermen and pearl oyster divers from Honolulu and Japan. With the exception of one case, small fishing boats (sampans) were either lost at sea or, having failed to reach their destination, were forced to return home. Intensive shelling operations were carried on, however, by one company who dispatched a schooner to Pearl and Hermes and on one of the islands erected several buildings which served as comfortable headquarters for our expedition.

The lagoon is about eighteen miles long and twelve miles wide. It is partially surrounded by a narrow strip of coral reefs which embrace it on the east, south and southwest, leaving the northern and northwestern sides unprotected. A series of islands, most of them merely sand bars, extends from the northwestern corner along the eastern and southern sides of the lagoon. The lagoon itself comprises a maze of small reefs and channels, with the depth of water varying from a few inches to 104 feet. The reefs growing inside the lagoon are made up by finger-like corals. The predominant forms, primarily responsible for the building up and maintenance of the encircling reef, belong to the species of Porites and Pocillopora, the colonies of which are strongly reinforced by the luxuriant growth of numerous nullipores. The rôle of these algae in building up reefs is probably equal, if not superior, to that of the corals.

Between the coral reefs the bottom of the lagoon is covered with shifting sand which, at the depth of about fifty feet, and below, is replaced by soft and sticky coral mud. Configuration, depth and

DR. CARL KOLLER RECEIVING A MEDAL

FROM THE NEW YORK ACADEMY OF MEDICINE IN RECOGNITION OF HIS RESEARCHES WHICH RESULTED IN THE DISCOVERY OF THE ANESTHETIC PROPERTIES OF COCAINE AND INAUGURATED THE ERA OF LOCAL ANESTHESIA. THE PRESENTATION OF THIS FIRST ACADEMY MEDAL IS BEING MADE BY ITS PRESIDENT, DR. JOHN H. HARTWELL.

distribution of reefs, sand and mud reflect the prevailing physical conditions and can be easily understood if one realizes that the present features of Pearl and Hermes, which in many respects can be regarded as a typical atoll, are determined both by the constructive forces of the reef-builders and destructive action of waves, breakers, wind, rain and various organisms, contrary to Darwin's well-known conception of atoll formation, which implies a gradual subsidence of the foundation and filling up of the lagoon with sediments, there are numerous indications that the material forming the floor of the lagoon is constantly being washed away and deposited at a greater depth outside the encircling reef. A comparison between the charts prepared in 1867 and in 1930 show noticeable increase in the area of the lagoon, especially at its southeastern corner. An important rôle in the destruction of coarse material of the lagoon floor and its reduction into fine mud is attributable to a large black bêche-de-mer, an organism measuring over a foot in length and weighing several pounds. Millions of these sluggish animals are found everywhere on the bottom, being especially conspicuous on the white background of the sandy shoals. Experiments with related forms, made in the atolls of the Indian Ocean and in Japan, show that the intestines of the bêche-de-mer of that size may contain as much as 88 grams of sand and that about half of that amount is ingested daily and passed through the intestinal tract.

Biological observations of the expedition consisted in making soundings, taking samples of bottom and water, temperature readings (top and bottom), determination of the alkalinity of the water, of its transparency and of its food content. For the examination of pearl oyster beds three divers were employed. They were directed to swim and dive for periods of time varying from half to one and a half hours. Because of the irregular distribution of pearl oyster beds the total number of the present oyster population of the lagoon could not be determined. However, from the data obtained during the investigation it is possible to determine the relative abundance of oysters, *i.e.*, the number of oysters found by the average diver during a given period of time. Biological observations just described were carried out at seventy-five stations uniformly distributed over the whole area of the lagoon. From a preliminary analysis of the data the following conclusions can be drawn:

The pearl oysters grow at the depth from 10 to 47 feet, attached almost exclusively to live corals. The average weight of the adult oyster is about two pounds; the maximum weight is seven pounds, but at present the oysters weighing over three pounds are rather scarce. The largest one obtained in 1928 weighed fifteen pounds. All the oyster reefs examined in the course of the investigation show obvious signs of depletion. The scarcity of the oysters is evidenced by the fact that on the best reef three divers were able to find in one hour only twenty-one oysters; on most of the reefs only three or four oysters were found during the same length of time.

One-year-old oysters were almost entirely absent. This fact indicates that either oysters failed to spawn and set in 1929 or that the 1930 crop was destroyed by fishermen. Because small oysters have a tendency to attach themselves to the shells of the adult ones, the second explanation seems to be very probable. Pearl oysters spawn and set in Pearl and Hermes lagoon in July and August. Two factors essential for successful spawning are high temperature of the water (27° C.) and an abundance of adult oysters on the reef. When the number of adult oysters on the reef is reduced to a certain low limit the oysters fail to spawn and their propagation ceases. The evidence supporting this statement is found by isolating single in-

A LONG-RANGE PHOTOGRAPH OF MT. SHASTA

TAKEN FROM AN AIRPLANE WHICH WAS 331.2 MILES SOUTH OF THIS POINT. THE PHOTOGRAPH WAS TAKEN ON AN INFRA-RED SENSITIVE PLATE BY CAPTAIN ALBERT W. STEVENS, OF THE U. S. ARMY AIR CORPS.

TAKEN FROM AN AIRPLANE WHICH WAS 331.2 MILES SOUTH OF THIS POINT. THE PHOTOGRAPH WAS TAKEN ON AN INFRA RED SENSITIVE PLATE BY CAPTAIN ALBERT W. STEVENS, OF THE U. S. ARMY AIR CORPS.

dividuals taken from badly depleted reefs, and those from the reefs that were not so badly overfished. In the former case, the spat was sparse or absent, while in the latter case it was abundant.

Pearls are procured mainly from the Sulu Seas, off the coast of Australia, Central America, Ceylon, Japan and some of the south Pacific islands. The ancient fisheries of Ceylon (Taprobane) are situated in the Gulf of Manaar, the fishing banks lying from six to eight miles off the western shore, a little to the south of the island of Manaar. The Tinnevelly fishery is on the Madras side of the strait, near Tuticorin. These Indian fishing grounds are under the control of government inspectors, who regulate the fisheries. The oysters yield the best pearls at about four years of age. Fishing generally commences about the middle of March, and lasts from four to six weeks, according to the season. The boats are grouped in fleets of sixty to seventy and usually start at midnight in order to reach the oyster-banks at sunrise.

Each boat generally carries ten divers. On reaching the bank a signal gun is fired and the diving begins. A stone weighing about forty pounds is attached to the cord by which the diver is let down. They work in pairs, and one man dives while the other watches the signal cord, drawing up the sink-stone first, then the haul of oysters, and finally the diver. On an average, the diver remains under water from fifty to eighty seconds, although there have been instances where some have remained as long as six minutes. The diver makes skillful use of his toes while under water; and to arm himself against sharks he carries iron spikes. The genuine Indian diver never goes down without the ritual of the shark-charmers.

Pearl-fishing is actively prosecuted along the western coast of Central America, especially in the Gulf of California, and to a less extent around the Pearl Islands in the Bay of Panama. Fishing grounds are in water about forty feet deep, and the season lasts for four months. An ordinary fishing party expects to get about three tons of shell per day, and it is estimated that one shell in a thousand contains a pearl. Dr. Galtsoff estimated that in the Hawaiian grounds at least ten per cent. of the shells carried pearls. He returned with 150 shells, fifty of which carried pearls of some size.

As is well-known, when a pearl oyster is attacked by a boring parasite the mollusk protects itself by depositing nacreous matter at the point of invasion, thus forming a hollow body of irregular shape called a "blister" pearl. Hollow, warty pearls are sometimes termed in trade *coq-de-perles* and all irregular-shaped pearls are known as *perles baroques*. A pearl of the best quality should be of delicate texture, free from speck or flaw, and of clear, almost translucent white color, with a subdued sheen.

Pearl oysters, of Pearl and Hermes Reef, produce valuable shells (mother-of-pearl) and bear large numbers of pearls. They represent valuable natural resource, which shows signs of depletion caused by over-fishing. It is estimated that since 1927, when pearl beds were discovered, more than 100 tons of shells (about 106,000 oysters) have been taken from the reef. It was, therefore, thought advisable to close pearl-oyster fishing and to forbid taking of pearl oysters in Pearl and Hermes Reef until the beds have been restored by natural propagation of the oysters. Several hundred pearl oysters were taken to Kaneohe Bay and planted on the reefs (near Coconut Island or elsewhere), where conditions are suitable for their growth and propagation.

When the pearl beds at Pearl and Hermes Reef have been restored they could be opened for fishing under government supervision, with such restrictions as it would be necessary to impose, in order to protect them from depletion and destruction.

## ARTIFICIAL LIGHTNING

RECENTLY, a small group of electrical engineers from the General Electric Company have been carrying out field experiments studying the effect of lightning on electrical power transmission lines. The work has been conducted at Croton Dam, in Michigan, where a forty-mile, 110,000-volt line was available as a tool for research. An artificial lightning generator was constructed for use as a portable impulse of 1,500,000 volts.

Mounted on a heavy trailer chassis and readily movable anywhere a motor truck might go, this lightning machine can send bolts of artificial lightning over a transmission line with startling reality. It can simulate to a remarkable degree of accuracy the bolt of natural lightning which might at any time strike a transmission line. In other words, it provided the way to take the waiting out of the game for the investigators. Had they been forced to wait for natural lightning, the experiments could never have been performed in the short time available. The equipment made it no longer necessary to wait in some remote place for lightning to come tumbling out of a cloud.

It was needful, also, to design and build a portable cathode-ray oscillograph in order to use the lightning generator to its fullest advantage. The oscillograph—a millionth-of-a-second camera—has the necessary capabilities for making records of the lightning surges over transmission lines. The varied characteristics of lightning waves and surges are studied from these photographic records, and from them engineers are able to make measurements of value in designing lightning arresters.

The lightning generator, once started, was almost automatic in operation. Its movements were governed by a Telechron clock in the circuit, which permitted the generator to discharge its million or one and a half million volts of man-made lightning with clock-like regularity once every sixty seconds. All measurements of the lightning were recorded in millionths or micro-seconds.

THE PORTABLE GENERATOR

CAPABLE OF PRODUCING A MILLION AND A HALF VOLTS.

NATURAL LIGHTNING

"BREAKING" OVER CROTON DAM, MICHIGAN.